SORGHUM AND MILLET IMPROVEMENT IN EASTERN AFRICA

Proceedings of the Fourth Regional Workshop on
Sorghum and Millet Improvement in Eastern Africa
22 – 26 July 1985
Soroti, Uganda

Sponsored and organized by:
Uganda Agriculture and Forestry Research Organization (UAFRO)
SAFGRAD/ICRISAT Eastern Africa
Regional Program, Kenya

UAFRO

SAFGRAD Semi-Arid Food Grains Research and Development

ICRISAT

1986

Editor and Workshop Organizer

Brhane Gebrekidan
SAFGRAD/ICRISAT Eastern Africa Program
OAU/STRC JP 31 SAFGRAD
P.O. Box 30786
Nairobi, Kenya

Local Programs Committee

V. Makumbi-Zake, Chairman

A.O. Dikan

J.P.E. Esele

B.W. Khizzah

Y.W. Mwaule

J.O.E. Oryokot

TABLE OF CONTENTS

PREFACE

The annual workshops of the sorghum and millet researchers of eastern Africa have now become well established and been conducted for the fourth time. The Soroti workshop will be remembered as one of the most successful ones although it was held during that momentous fourth week of July 1985 when Milton Obote's government was toppled. The regional workshops have contributed significantly in strengthening the Eastern Africa Sorghum and Millet Improvement Network and cementing the bond of friendship among the sorghum and millet workers of the region.

The main contributors to the Soroti workshop were the Uganda Agriculture and Forestry Research Organization (UAFRO), the Semi-Arid Food Grains Research and Development (SAFGRAD) of the Organization of African Unity (OAU), and the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). Several other organizations also contributed by sponsoring invited speakers and participants. The contributions of all the organizations which made the Soroti workshop a success are gratefully acknowledged.

Of all the workshops held so far, the Soroti one had the largest number of papers presented both from the host country and from outside. The edited versions of most of the papers as well as discussions on each paper are contained in these proceedings. I believe that they are significant additions to the eastern Africa sorghum and millet proceedings series which are widely used references.

Caroline Agola assisted in editing and Margaret Sandi typed all the papers. Their contributions are acknowledged with appreciation.

Brhane Gebrekidan

WELCOMING ADDRESS

Vincent Makumbi Zake*

Distinguished delegates, ladies and gentlemen,

On behalf of the Uganda Sorghum and Millets Research Unit, it is my pleasure to welcome you and to extend sincere thanks to each of you for having accepted the invitation to participate in the Fourth Regional Workshop on Sorghum and Millets Improvement in Eastern Africa.

For many of you, this is your first visit to Uganda. Soroti is in the extreme eastern part of the country and it is more than 200 miles from the capital, Kampala. As you may have observed, Soroti is quite a small town. This is a place where sorghum, finger millet, cassava, groundnuts and cowpeas are grown abundantly. Almost every homestead has cattle. Mangoes and oranges are important fruit in the district. Fish is a part of the daily diet.

I wish to thank the Director of the East African Civil Aviation School for offering us the use of these premises and facilities to host the workshop. I also wish to thank the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and the Semi-Arid Food Grains Research and Development (SAFGRAD) project of the Organization of African Unity (OAU) for organizing and sponsoring the workshop and for bringing together scientists from the region and beyond. Special thanks go to IDRC for financial support of our project; to officials of the Ministry of Regional Co-operation, the Ministry of Agriculture and Forestry, and the Ministry of Planning and Economic Development, and the Faculty of Agriculture, for co-operation. Sincere thanks are also due to the Director of Serere Research Station for his support in the preparation of the Serere Field Day. Once again, I thank you and wish you a successful week and an enjoyable stay at Soroti and in Uganda as a whole.

---

*Principal Research Officer-in-charge, U.A.F.R.O., Sorghum and Millets Research Unit, Serere Research Station, P.O. Soroti, Uganda.

O P E N I N G   A D D R E S S

K. Nakimwe*

Distinguished representative of Semi-Arid Food Grain Research and Development (SAFGRAD), distinguished representative of International Crops Research Institute for Semi-Arid Tropics (ICRISAT), distinguished representative of International Development Research Centre (IDRC), ladies and gentlemen:

My Minister, the Honourable Sam Tewungwa, Minister of Regional Co-operation, has sent me to open this important workshop. He has sent me to bring greetings to all participants, whether from home or abroad.

It is with pleasure and pride that we welcome the choice of our country to host this workshop. To us this signifies your confidence in the Republic of Uganda, and we are well aware of the benefits of strengthening national research programs and international collaboration.

This meeting of research scientists concerned with sorghum and milllets improvement in eastern Africa is an example of the kind of horizontal transfer of technology on which our countries place increasing reliance. Scientific solidarity has become the key to emergence from underdevelopment. We thank ICRISAT, SAFGRAD, and IDRC for holding this workshop in the eastern Africa region and we welcome their representatives to Uganda.

Coutries in eastern Africa have much in common. We are linked by history; have large land masses which in most cases have poor soils and are dry; and weather which is unreliable, with the result that we share a number of social, economic, political and scientific problems. In all these countries, subsistance farming is the norm. Sorghum and millets are the traditional staple crops grown by farmers for food consumption. This explains the farmer's reluctance to experiment with the survival of his family and the resulting slow rate of adoption of new varieties. Population increases have led to over-cultivation and a reduction in fallow periods and the amount of land reserved for pasture. As a result, both the yields and fertility are declining and overgrazing, along with soil erosion, have become major problems. As if that were not enough, recently we have suffered from periodic food shortages due to persistent drought.

---

*Permanent Secretary, Ministry of Regional Cooperation on behalf of Hon. Sam Tewungwa, M.P., Minister of Regional Co-operation, Republic of Uganda.

Sorghum and millets are low-technology-input crops. Production inputs such as fertilizer and plant-protection materials are beyond the means of the local farmer, and in any case our countries lack well-organized markets and storage facilities for surpluses. This is mainly due to the lack of agriculture-based industries and a tiny non-agricultural population; and many cultivators tend to offer the same products for sale simultaneously so prices are low. It is, therefore, essential for you scientists to determine priorities for research and development after taking into consideration the resources and objectives of the farmers and existing research and institutional policies. Realism demands low-input technology which must be economically feasible. In this connection I wish particularly to thank the International Development Research Centre for assisting sorghum and millets research in Uganda and encouraging our scientists to think and work along the lines of farming-systems research.

We await your findings with confidence. We hope to use them in our fight against the basic problems of sorghum and millets production in order to help us attain our national and regional goals of independence in food resources.

I take this opportunity of thanking the officials of SAFGRAD and ICRISAT for organizing the workshop and for bringing together sorghum and millets research scientists from various parts of the world. My Ministry, true to its function and obligations, will be happy to play its role in effectively co-ordinating regional co-operation for the benefit of all.

I, therefore, declare this workshop open and wish you success and an enjoyable time in Uganda.

LOOKING BACK

H. Doggett*

Mr. Chairman, Mr. Permanent Secretary to the Ministry of Regional Co-operation, Mr. District Commissioner, distinguished delegates and friends:

It is a great pleasure to be back in Uganda, to be here in Teso, and especially in Soroti; very much home from home. Jane would like to be with me, she sends her greetings.

This morning I realized that I had forgotten my African habit of knocking out my shoes before putting them on. On putting my foot into my right shoe, there was an obstruction in the toe: while trying to remember what I might have packed there, the obstruction moved - and so did I! A large toad jumped out and hopped across the hotel room floor.

It is also a great pleasure to be with a group of scientists who are still carrying on the good work here in Africa of helping people to feed themselves and their families more effectively. Many of you are working under difficulties. I was attracted to this work by the records of Christ in the Christian gospels: he had compassion on the crowds because they were hungry, and in one account turned to his disciples - his close followers - and said "You give them something to eat".

You will all be talking a great deal about millet and sorghum, so let me fill in a little historical background, leaving my few words on sorghum and millet until the end.

When I use the pronoun "we" in this talk, I am thinking of the team of local staff who were really responsible for getting the research work done, both here and at Ukiriguru in Tanzania: teams which my colleagues and I had the privilege of leading. Many of those men and women are still carrying on the good work.

I was posted to Serere in August 1958, having transferred from the Government of Tanzania to EAAFRO earlier that year. A glance at the EAAFRO reports for 1958 and 1959 reveals that H.H. Storey was making good progress in breeding for resistance to cassava mosaic, and also to maize streak virus. He was also studying the resistance of maize to the rust *Puccinia polysora*, and had made the remarkable discovery that only some of the vector insects (*Cicadulina mbila*) were carriers of the disease.

---

* 15 Bandon Road, Girton, Cambridge, CB3 OLU, U.K.

H.F. Birch was making interesting discoveries on the effects on the release of nitrogen of drying and wetting soils: and its relationship to soil organic matter. H.C. Pereira and his team were studying the relationship between water and crop growth in catchment areas (now called "watersheds"). They were horrified to find that in overgrazed Karamoja thorn-scrub livestock trampling had so reduced rainfall infiltration that moisture had penetrated to a depth of only one foot, although more than 25 inches of rain had fallen. A few references are given at the end of this paper.

Serere Research Station was at an expanding stage of development in 1958. there was, of course, an active cotton breeding and agronomy program - cotton was king. Walter Hirst had done a very good job of gathering, maintaining and improving varieties of maize, finger millet, sorghum, bulrush (pearl) millet, groundnuts, beans, sesame, cassava, sweet potatoes, Deccan hemp (Hibiscus cannabinus), as well as running a centre from which a wide range of clonal fruit trees - mostly citrus were sold at very low prices. There was an active pasture program, with C.R. Horrel demonstrating the value of legumes in increasing total herbage production, together with the importance of management. The livestock program worked in closely. D. Joblin had overthrown the traditional elite-dairy-herd approach, that of getting a few more gallons of milk each year. David was selecting for animals that could give good liveweight gains on grass or grass and legume only, while producing a minimum of 200 gallons of milk per lactation; and which had some resistance to East Coast Fever. He wanted an animal that the farmer could use, while Dick Horrell was finding out how the farmer could feed it.

The maintenance and improvement of soil fertility has always been an important Serere activity. The long-term fertility experiment had already been running for more that 20 years, while the permanent manurial trial had been continuously cropped on a three-year rotation since 1933. Many fertilizer and manurial trials had been done on crops and pastures. (In Serere terminology, a pasture was a "ley", a variant of the word "lea", a Middle English word from Anglo-Latin, referring to land laid down for pasture or grassland. Leys were mostly temporary, lasting for a very few years before going back under the plough for arable cropping). Soil erosion was minimized by leaving grass strips across the slope at appropriate intervals, but many soil erosion methodologies had been tested. There was a soil chemist, and an entomologist: but the pathologist's post was usually vacant. The 1960 annual report stated that "Mr. Warren arrived to fill the new post of Agricultural Officer (Ox Cultivation)". That seems a good year to choose as the starting point to consider some of the research results and directions of the program.

Let us first look back at the philosophy behind that program. The Uganda Government's original concern had been to generate revenue. The whole infrastructure was new to the country, and had to be paid for. A salaried civil service, road and communication systems, education and schools, health care with dispensaries and hospitals, police, prisons and law courts, all needed both capital expenditure and recurrent money for paying salaries and wages. In addition, there was a large body of staff helping in government departments such as Agriculture, Forestry, PWD, Lands and Mines. All these needed money. The cotton industry in Britain was interested in having a dependable supply of cotton lint, and was prepared to put some money into cotton growing and ginning overseas. The cotton crop became important for the Ugandan economy, and was encouraged in Buganda (where conditions were really too wet) and in the east and north, in parts of which cotton was better adapted. During the period 1917-1919, two or three sites for a cotton station in Teso were tried, and finally, Serere Research Station was established in 1920.

It was intended that cotton should be the main economic crop, and other annual crops must be adjusted to fit in with the cotton crop. Today, this may seem incredible: but Britain was an industrial country, and many of the colonial civil servants of those days, certainly the policy makers, would have grown up in cities with little understanding of agriculture, and with a decided bias towards the needs of industry. It was most unusual for anybody with an agricultural degree to rise to the higher decision-making echelons.

As an aside, the supremacy of cotton was the reason for my coming to Uganda. I was happily working on sorghum and rice at Ukiriguru, and doing a little on other crops as well, as opportunity offered. However, Ukiriguru was a cotton station, and Heliothis (American Boll Worm, or ABW as it was then called) was being troublesome to the cotton crop, especially in the station trials. The day that I discovered ABW feeding happily in dense sorghum panicles, my fate was sealed, unbeknown to me. I soon learnt that we were to be transferred to Ilonga. We had four children and schooling at Ukiriguru had been easy, as we could put the kids on the lake steamer in Mwanza, a friend collected them at Bukoba, and drove them up to the Kigezi boarding school run by the Ruanda Mission for the children of their staff. We simply did not see how to manage schooling from Ilonga at all. Our problems were solved by Dr.E.W. Russell, who offered me a job at Serere. Schooling was available across the border in Western Kenya, and the Uganda Government paid 120 per year for each child at boarding school in Kenya. The East African Community followed the terms of service of the country in which their staff were located.

Serere being a cotton research station, the basic research policy was to work out the optimum growing conditions and requirements for cotton, and then to discover how all other agricultural activities could best be made to fit in around cotton. Such a system was seen as economically the best for Uganda, and therefore the best for the local farmers to adopt. The basic thinking at the top policy level was that the research station should develop a productive agricultural system and the extension service should teach it to the farmers. Everyone would be much better off as a result. The intention was to raise the standard of living of the farmer, and to give him and his family a better life. Unfortunately, the farmer was not consulted ("he would not understand, would he?") and this altruistic dream did not have the hoped-for impact. Few paid much attention to the traditional agriculture of the farmers: the new would be so much better. In fact, at Serere there was always a great concern about having good contacts with the farmer. We just did not have the cropping-systems methodology so successfully developed ten years later in S.E. Asia. The achievements of the Serere Research Station team are impressive. The two editions of Agriculture in Uganda provide a good record of outstanding work. I can say this because I was an outsider, from the East African Community.

The cotton program

Looking first at cotton, experimental results established that a planting date before 7 May in Teso, and in much of east and north Uganda, gave the best yields; in any case, the crop should be sown before mid-June. In practice, 40-50% of the crop was planted in July and August. Stephen Carr has argued that, under farmers' conditions, late planted cotton produces relatively well. One guesses that competition for labor on the other crops was a major factor. Finger millet was the main food crop, and farmers needed to get their food crops in, weeded, and even harvested, before giving serious attention to cotton.

Close spacing was recommended for cotton: 2 feet x 6 inches (about 60 x 15 cm) was considered optimum for cotton sprayed with pesticides. Originally, 3 feet x 1 foot (90 x 30 cm) had been recommended: actual spacing in farmers' fields was much wider than either. Pests were troublesome, especially boll worms and *Lygus*, and spraying was considered essential. Four sprays with 1 lb DDT per acre were recommended, at 14-day intervals, starting on the 35th day after planting.

Cotton needed to be graded before sale, and this was a laborious process. Appreciable amounts of cotton were often left in the field unharvested. In order to reduce pests, the cotton plants had to be uprooted and burnt at the end of the season.

Much effort went into pressuring farmers to adopt this proven system for cotton growing. Much labor and effort was required from the farmer: the reward from using the "full package of practices" was often not commensurate with the effort involved.

The "supporting program"

The system built around the cotton crop was based on rotational cropping: yields were usually low after three years of cropping. Instead of land rest under natural "tumbledown" fallow, temporary leys were developed. There was a large cattle population in the east and north, and these leys would have provided organized grazing for the livestock. Local grasses such as Hyparrhenia rufa established easily, and provided good grazing so long as the grass was grazed often enough. Stylosanthes could be broadcast into the grass, providing a grass-legume mixture that gave more herbage than grass alone. Addition of single superphosphate gave much greater herbage prodution. Rock phosphate also works well, but a sulphur source may be needed. Grazing management is essential to obtain the best results, so some form of fencing or enclosure is required.

The manurial and fertility trials are well worth studying: under continuous cropping, crop yields in a rotation were better than those from continuous monocropping. The permanent manurial trial indicated that soil fertility can be maintained under 10 tons of farmyard manure applied every three years. The fertility experiment showed that fallowing had very beneficial effects on the following crops, but if enclosure manure was applied the same benefits could be obtained as from fallowing. One striking feature of the fertility experiment was the effect of ox ploughing. After being hand-cultivated for about 30 years, the introduction of ox ploughing resulted in big responses on all the sorghum and millet treatment plots but not on the control plots. Cotton and cassava showed very little response.

Which brings me to the third area that I want to pick out - that of ox cultivation. Ox ploughing has been widely practised in Teso and beyond since the early 1920s; it probably began about 1909. Other ox-drawn implements have not caught on at all widely. The lack of a suitable seeder is surely the main reason for this. It is usually necessary to plant fast, because of soil moisture conditions, so broadcasting is used - or the heel-and-toe system. Neither gives rows straight enough for inter-row cultivation. A good seeder would do this. The Serere ox-cultivation unit had developed a good seeder, modelled on the Bentall and known as the A & H Seeder since it was produced by A & H Engineering here in Soroti. It is larger than the Bentall, with over three times the capacity for seed. The filling hole has a pivoted cover, and the seeder rotates on sealed ball bearings.

A bracket was designed to take two seeders running in parallel rows, and a simple tool-bar: the "Usena" seemed suitable for mounting tines. I was very encouraged to learn on my last visit here that A & H are back here in Soroti and have already started making the seeders again. The polycoulteur tool-bar was being tested at Serere some 20 years before ICRISAT was examining it in India. Here, where oxen are smaller than in India, the tool-bar needed too much draught power. Above all, it was too expensive.

Farming systems

Today, here in Teso, you are in a very different situation from that prevailing 25 years ago. There is a strong demand for agricultural produce in the cities, especially in Buganda: there is also a strong demand across the borders. This provides a unique opportunity to get some of these improved practices across to farmers because they maintain soil fertility and increase production. Produce now has a high commercial value. I suggest that you look very carefully at the farming-systems approach, and work to build close links with the farmers. The part played by farmers in farming-systems research is fundamental: yet it is sometimes presented as though it was a substitute for research on experimental stations. Nothing could be further from the truth: thorough, sustained component research is fundamental for effective farming-systems research. You have an abundance of good, relevant research results on Serere Research Station. They need to be developed with farmers so that they can be used by farmers. I would pick out three most important aspects:

1. The value of raising cattle on grass-legume mixtures with a little phosphate added, thus improving the fertility of the land under the ley;
2. The importance of improving fertility through crop rotations, and through the application of organic manure and inorganic fertilizers. The farmers know a lot about this already;
3. The importance of developing ox cultivation, not only for ploughing to give better cereal yields, but also to do much of the seeding and much of the weeding. A lot of labor can be saved thereby, and during the season, labor is the farmers' main constraint.

Crops

Serere has made much progress in sorting out or developing superior strains of crops. Millet, sorghum, maize, cassava, sweet potato, sesame and other oilseeds, groundnuts, cowpeas, green gram, black gram and tepary beans are among the crops on which breeding and selection work has been done. There is plenty of room for more such work, especially in breeding for disease resistance, optimum maturity lengths, and good, vigorous stand establishment with strong early growth.

In view of the brisk sales of cassava and sweet potatoes outside the district, as well as their use for feeding pigs, the root-crop project seems very appropriate. I hope that root-crops agronomy will be studied also, especially the rotational and soil-fertility aspects.

Short-term cassava types may be worth looking at: in Sri Lanka some sweet types taking two and a half to five months are being grown for sale into Colombo: and it is possible to get two crops a year on a rainfall distribution not very different from that of Serere. (Material would be available from the Bombuwela Research Station). As soon as disease-free tissue-cultured material is available, these types should be tested out at Serere. These types do not store, they are for use immediately after harvest. The sweet potato work at VISCA in the Philippines is exceptionally good. They are using the polycross breeding system very effectively. A little time spent there would be most useful for the sweet-potato breeder.

Sorghum and millets

This is a sorghum and millets workshop, and all of you are here to do the talking on this subject. Twenty years ago I would indeed have done my share of the talking: now it is your turn.

Finger millet is an important crop with a good yield potential. On the agronomy side, I would urge more attention to the use of the AH seeder. Weeding is the bugbear of this crop, and row seeding would be a great help. Transplanting is another way of obtaining early weed control, much used in South India. Herbicides are rather a long shot: the risk of herbicides being used in the wrong crop is high. I would urge a great deal of attention to the varieties that the farmer is actually growing now, how he grows them, why he grows them. Get <u>his</u> list of faults and needs in the crop to establish the breeding objectives. They are likely to differ from area to area. The white grain has been lised as a breeding objective. I have doubts: what about damage from birds and from gain moulds? This should be carefully looked at.

One of the problems of working with finger millet in the past was the difficulty of making crosses. Now that a male-sterile is available, developed at Serere, populations composited from several good varieties should prove to be a useful source of selections which would then go in to traditional progeny-rows.

Bulrush (pearl) millet probably does not deserve a lot of attention, as the area under the crop in Uganda is small. Mass selection in composite populations should be continued, and this selection should be done in Karamoja as far as possible.

Have the ICRISAT populations been looked at recently? It may be worth getting the latest populations, and growing them under mass selection for two or three seasons before putting on a higher selection pressure.

The objectives of the sorghum program should be looked at critically: originally it served the three countries which formed the East African Community, and there was a strong demand for white, flinty, mould-free grain types. How much demand is there in Uganda for these? In Teso, they can be grown in the second rains quite successfully. How large an area is suited to white sorghums? Birds are a major menace in the country. In Tanzania I had been working on bird resistance, trying to combine together characters that would make sorghums unattractive to birds. Among those tried were goose-necks (recurved peduncles giving an inverted head), close heads, awns, and large, papery glumes completely enclosing the grains. These characters were proving difficult to put together in agronomically desirable plant types with good yield. I brought the material up to Serere, and planted it in the citrus nursery area at the beginning of the main rains. The yellow weavers and the bishop birds had a wonderful time. They squeezed the large glumes so that the soft grain popped out at the end, to be swallowed up. Those birds were just as happy feeding upside down as the right way up, and simply ignored awns. I can still remember my fierce sense of frustration as years of work and dreams of sorghum ideotypes that would transform the sorghum areas of East Africa were gobbled up before my eyes.

I have no doubt that Africans in many areas learnt the hard way, and accepted bitter grains as inevitable because of the birds. They had to learn how to use them. Much more is now known about kinds of bitterness - thus Seredo grain is more acceptable for food than is Serena. It is essential to follow up on the quality and uses of brown grains, and large areas of brown grains will have to be grown until the countryside has been so extensively brought under detailed management that bird populations are much reduced. That will not be for a long time - and meanwhile, Serere is very well placed for work on brown sorghums. The amount of effort that goes into a white flinty sorghum program must depend on the amount grown in Uganda, or at least, on the potential "bird-damage free" area available.

I have always felt that the really important sorghum discovery made in the Serere program was the relationship between the yield of sorghum hybrids and the yield of its better parent, or of a widely grown elite variety. The difference in yield between the hybrid and a good variety is constant over a wide range of yield levels: there is no variety times x environment interaction.

Hybrids have a great future in Africa: but the problems of seed production and of distribution to the farmers are very great. When I was at ICRISAT, we felt that once a national program has developed hybrids, it is likely to have the human resources to multiply hybrid seed. Until then, varieties and populations would be more valuable. Therefore, we went in for recurrent selection which would provide a steadily improving source of better varieties. Good hybrids can ony be made from good varieties.

This seed- production problem has been very frustrating: a seed production scheme was developed at Masindi with ODA support: but it was overtaken by the times of trouble. There is no possibility of introducing hybrids without proper seed multiplication and distribution. To do so could be disastrous: they would be grown for more than one generation and would then get a bad name from the growers. The segregating male-steriles would get honeydew disease, and the segregating generations would contain a lot of undesirable plant types.

However, the potential value of hybrids should be kept in mind. ICRISAT has one or two good B populations (non-restorer), as well as R populations. These should be obtained. Some of them contain a good proportion of Serere material. They have white grains, so would need to be grown in the second rains, while brown grains are being introduced: but it should be possible to derive some good B and R lines from the populations which would be worth testing as superior varieties for the present, but which would have great value as potential hybrid parents. Good hybrids have good varieties as parents.

May I make a few suggestions?

1. Look at what the farmer is doing. Look for possible fresh crop sequences and rotations. Watch the weed problem.
2. Don't forget the cattle populations - they could contribute more towards building up soil fertility, and thus to improving farmers' incomes.
3. Keep working on ox cultivation - learn how to grow both millet and sorghum with implements the farmer can afford and can use. Work with him. Ox-drawn implements will help to implement better erosion control.

I look forward to some very interesting presentations and discussions.

REFERENCES

Birch, H.F. 1958. The effect of soil drying on humus decomposition and nitrogen availability. Plant & Soil 10: 9-31.

______ 1959. Further observations on humus decomposition and nitrification. Plant & Soil 11: 262-286.

______ 1960. Nitrification in soils after different periods of dryness. Plant & Soil 12: 81.

Carr, Stephen 1982. The impact of Government intervention on smallholder development in north and east Uganda. A.D.U. Paper No. 5, School of Rural Economics, Wye College University of London).East African Community. Records of sorghum and millet research. EAAFRO, Muguga, Kenya. 1958-72.

Pereira, H.C. (1958). The limited utility of flood water in the Perkerra river irrigation scheme. E.Af.Agric. J. 23: 246-252.

______ . et al 1958. Water conservation by fallowing in semi-tropical East Africa. Emp.J. Exp. Agric. 26, 213-228.

______ . and J.S.G. McCulloch (eds.) 1962. Hydrological effects of changes in land use in some East African catchment areas. E. Afr. Agric. For. J. 27. Special issue.

Storey, H.H. 1961. et al.1961. Vector relationships of plant viruses. E.A. Med J. 38 215-220.

Storey, H.H. et al. (1958). East African work on breeding maize resistant to the Tropical American rust Puccinia polysora. Emp. J. Exp. Agric. 26: 1-17.

Storey, H.H. (1961). Vector relationships of plant viruses. E.A. Med. J. 38 215-220.

DISCUSSION

Mwaule

May I ask Dr. Doggett to comment on the role of genetic engineering in plant breeding?

Doggett

The transfer of small segments of DNA from one genus to another, and between species, has been demonstrated. Using Ti plasmids, there is little doubt that within five years it will be quite possible to transfer genes by "genetic engineering". The problem is knowing what to transfer and how much can be transferred. Single genes for characters such as disease resistance, which can be identified on the genome as a small segment of DNA, can certainly be transferred. Many genes remain to be identified in this way, and until this is done, genetic engineering cannot help. Complex expressions such as high yield may be difficult to handle for a long time. There are probably a very few major genes that are important - but we have got to learn a lot more about complex character expressions involving many genes before transfer can even be continued. Tissue culture has a more immediate potential. Anther culture, in particular, could halve the time taken to develop a new variety, and this does deserve immediate study. Dr. Axtell is much more up to date than I am: his comments would be helpful.

Axtell

Plant genetic engineering provides some extremely valuable tools for the geneticist to study gene regulation, gene structure and gene organization in higher plants. The new knowledge and understanding gained will undoubtedly provide some useful techniques for plant breeders in the future. At this point in time no one can be certain in what areas plant genetic engineering will provide breakthroughs for the plant breeder. Even when these occur, it is unlikely that they will revolutionalize plant breeding. Rather, they will provide additional tools which will supplement on-going plant programs.

For the present, it is important to continue development of strong crop improvement programs using conventional techniques. We know a great deal about how to improve plants using tried and proven methodologies. The best attitude is to continue strengthening conventional crop improvement programs utilizing interdisciplinary team effort. These strong programs will be in the best position to capitalize on new techniques from genetic engineering when they become available.

BACKGROUND AND PURPOSE OF THE WORKSHOP

Brhane Gebrekidan*

The Eastern Africa Sorghum and Millets Improvement Regional Workshop is now a well established and accepted annual affair. The last three workshops were held in 1982, 1983, 1984 in Ethiopia, Rwanda and Tanzania, respectively. The 1984 workshop recommended that this year's meeting of eastern Africa sorghum and millet workers be held in Uganda. The recommendation was accepted with enthusiasm by our Ugandan colleagues and for the last several months they have spared no effort in preparing for this meeting.

Complete records of the last three workshops are contained in the Proceedings, which have been published and distributed. As all of you who participated in the previous workshops will recall, they were financially supported by IDRC, a support of which we are most appreciative. IDRC have now handed over the financing of these workshops to SAFGRAD/ICRISAT.

This workshop has three main sponsors and organizers, namely the Uganda National Sorghum and Millet Program, the Semi-Arid Food Grains Research and Development (SAFGRAD) of the OAU/STRC, and the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT).

During this workshop our focus of attention is the world famous Sorghum and Millet Research Station, Serere. We are fortunate to have the person who has done most to make Serere famous deliver the keynote address and be with us in our meetings. We will continue to hear a lot more about sorghum and millet and Serere from our Ugandan colleagues in the next four days.

With reference to the timing of the workshop: it was planned to be at the best time for seeing the crops of our interest in this part of Uganda. I am confident that you will have plenty of opportunity to get a good visual impression of the crops both at the Station and in the farmers' fields.

The main purpose of this regional workshop, as in the past, is to enable the sorghum and millet researchers of the region to participate in peer review of their programs, to continue to effectively share experiences, and to give them a continuing

*SAFRGRAD Co-ordinator for Sorghum and Millets, Eastern and Southern Africa, ICRISAT/SAFGRAD Regional Program, OAU/STRC/SAFGRAD JP 31, P.O. Box 30786, Nairobi, Kenya.

opportunity to interact with each other and to further discuss the problems, solutions and prospects of sorghum and millets improvement in the region. The workshop is expected to strengthen even further the existing linkages among the national sorghum and millets programs of the region so that the flow of information and germplasm in all directions is facilitated.

Our last workshop in Tanzania concentrated on that country's national sorghum and millet improvement program. In addition, country papers and results of the 1983/84 Eastern Africa Co-operative Sorghum Regional Trials were presented and discussed. During this workshop there will be no presentations of the regional trials because in most locations the 1985/86 trials have only just been planted. This year, in addition to the regional trials, a regional sorghum nursery of 1,000 entries has also been organized and sent out to four selected countries (Ethiopia, Kenya, Tanzania and Uganda). After evaluation, the most promising entries across locations will be distributed to all of the national programs of the region.

The papers to be presented in this workshop fall into three categories - host-country papers, visiting-country papers, and invited papers. In the host-country session, we are scheduled to hear about 20 papers in crop improvement, agronomy and seed production, crop protection, and utilization. Compared to our past workshops, the host-country papers make up a large proportion of the total, indicating the seriousness and the high interest level of our Ugandan colleagues. Emphasis on all aspects of the national program of the host country is consistent with our past practice. We are here to learn about the Uganda sorghum and millet program as much as possible and to discuss it.

The visiting-country papers are expected to be equally interesting because papers on completed experiments on specific topics have been requested from each country. A second section of each country's report is to highlight the national sorghum and millet research activities of the last season and to comment on the national research plans for the current or coming season.

In the invited-papers session, we are fortunate to have four prominent scientists who are scheduled to speak to us on millet breeding, sorghum nutrition and utilization, sorghum leaf diseases, and *Quelea* control strategies. Participants will recall that these are all topics which were identified as having special interest and significance in our region.

Finally, last year in our Morogoro workshop we highlighted the severity of the drought in Africa and the crucial role of sorghum and millets production under moisture-stress situations. Africa's catastrophic drought and famines have taken over the headlines of the international news media for months, attracted several international and regional conferences, including the current OAU summit, and have even been the subject of one of the greatest musical and television shows of all times. Africa's declining food production, and the heavy toll in starvation and human suffering are likely to continue. Sorghum and millets will have to continue to play a prominent role in alleviating the deteriorating food situation in Africa. It is a challenge to us and an opportunity to generate technologies that will improve and stabilize sorghum and millet production in our region. If we are to succeed in these efforts, we have to continue to strengthen our regional co-operative activities.

We look forward to four most interesting days packed with information and visits that will make our stay in Uganda memorable.

Thank you.

OVERVIEW OF SORGHUM AND MILLETS RESEARCH IN UGANDA

Vincent Makumbi Zake*

Agriculture constitutes the most important sector of Uganda's economy. It provides employment for over 80% of the country's 15.3 million peopole.

The country's policy places emphasis on self-reliance in food resources whilst improving the production of export crops and livestock. The importance of food crops such as maize, sorghum, finger millet, banana, sweet potato and cassava has increased tremendously as compared to cash crops. The areas covered with sorghum, finger millet and bulrush millet exceed 950,000 hectares, or 70% of all crops. By area, the relative importance of finger millet, sorghum and bulrush millet is 55, 42 and 3 per cent respectively.

Sorghum is the most widely grown cereal in Uganda. It is grown mainly in the short-grass areas of the north and east of the country and is particularly important in the drought-prone Karamoja region. Sorghum is a staple crop in the Kigezi District and is also interspersed with other crops throughout the country for the traditional sorghum beer and for mixing in banana brewing. In 1983, sorghum covered an area of 230,000 hectares which resulted in 470,000 metric tonnes of produce. Although in terms of area planted sorghum is the third most important cereal after maize and finger millet, production figures for 1983 indicate that the total yield was higher than for maize. This may be attributed to maize crop failures due to persistent drought in certain areas of the country.

Uganda has extensive genetic variability in sorghum and finger millet and local types of both crops are widely grown as they are preferred for food and brew (Zake, 1982). Although improved varieties of sorghum (Serena, Dobbs Bora, Lulu Dwarf, Lulu Tall and Seredo), finger millet (Engeny, Serere 1, Gulu E and P 224), bulrush millet (SC 1 and SC 2) have been released to farmers of the former East African Community, only Serena, Seredo, and Engeny are marketed through seed schemes in Uganda. The released varieties have not all been fully accepted by Ugandan farmers and consumers.

---

*Principal Research Officer in Charge, UAFRO, Sorghum and Millets Unit, Serere Research Station, P.O.Soroti, Uganda

Intensive sorghum improvement in Uganda was initiated in 1958 and finger millet and bulrush-millet improvement followed in 1965. The sorghum and millets improvement project is responsible for undertaking research in the improvement of these crops in Uganda. The Sorghum and Millet Unit was one of the research divisions of the former East African Agriculture and Forestry Research Organisation. Currently the research work is being administered by the Ministry of Regional Co-operation.

The objectives of the sorghum and millets improvement project are:

Sorghum

1. To select for high yielding disease and pest resistance and most acceptable grain sorghum varieties and hybrids consistent with the prevailing bird damage situation.

2. To select drought escaping or tolerant sorghum varieties suitable for the more difficult Karamoja areas.

3. To develop high yielding varieties suitable for the high altitude areas of Kigezi District.

4. To develop high yielding ratooning varieties for the banana brewing areas.

5. To understand the epidemology of the leaf diseases and grain mold causal organisms and identify sources of resistance to these diseases and utilize these sources in developing resistant cultivars with good agronomic traits.

Finger millet

1. To continue to evaluate the performance and adaptability of the improved finger-millet entries screened from the existing program in as many environments as possible.

2. To study the biology and epidemiology of blast disease, develop effective blast-resistance, and utilize resistant materials in blast resistance breeding.

3. To assemble and establish a large finger-millet germplasm, including populations.

4. To continue to select for lodging resistance.

5. To develop and select for higher viability and seedling vigour.

Bulrush millet

1. To improve early maturing bulrush millet populations using recurrent selection methods.

2. To continue to evaluate improved composites over several locations of the low rainfall and poor soils of Uganda.

3. To select varieties and composites resistant to lodging, stem borers and birds.

4. To assemble a large number of bulrush millet collections from centres of diversity for breeding use.

Based on the existing agricultural zones (Zake, 1982) ancillary services have been developed by the Ministry of Agriculture and Forestry which enable the Serere breeding work to screen varieties in a number of localities.

The Uganda Seed Company is being rehabilitated. Multiplication and distribution of sorghum and millets is being done through the Church of Uganda's Karamoja Seed Scheme, prison farms, and the Serere Research Station.

The sorghum and millets project looks forward to a bright future having been assured of another four years of financial assistance by the International Development Research Centre (IDRC). There has been an appreciable level of manpower development through ICRISAT.

REFERENCE

Zake, M.V. 1982. The status of sorghum improvement in Uganda. In Proceedings of the Regional Workshop on Sorghum Improvement in Eastern Africa held in Nazreth and Debre Zeit, Ethiopia. SAFGRAD/ICRISAT Eastern Africa Program, Nairobi. pp 141-150.

REMARKS ON THE SORGHUM AND MILLETS GERMPLASM WORK IN UGANDA

J.R. Okello*

In the Uganda Agriculture and Forestry Research Organisation (UAFRO) at Serere, the sorghum and millets germplasm work includes efforts to assemble, characterize, evaluate, document, utilize, distribute, and maintain germplasm.

In collecting within Uganda, the IBPGR standard forms are used for records of passport data. At the end of 1984 and beginning of 1985 three collecting missions were conducted to collect sorghum and millets in northern, eastern and western regions of Uganda.

A total of 311 accessions of sorghum, 342 accessions of finger millet and 20 accessions of bulrush millet were collected from northern Uganda. These materials were collected at altitudes ranging from 520 to 1,480 m altitude.

From the eastern region, a total of 149 accessions of sorghum, 90 accessions of finger millet and only one accession of bulrush millet were collected. The altitude in the collection area ranged from 1,190 to 1,400 m.

From western Uganda, 274 accessions of sorghum and 252 accessions of finger millet were collected. No collections of bulrush millet were made from this region.

---

*UAFRO, Sorghum and Millets Unit, Serere Research Station, P.O. Soroti, Uganda.

FINGER MILLET BREEDING IN UGANDA

Bill W. Khizzah*

Finger millet (Eleusine coracana Gaerton) is one of the most important cereals in Uganda. It is the staple food for more than 50% of the country's 15.3 million people. The grain stores well and has few insect pests. It can easily be ground with the simple equipment possessed by peasant farmers. The grain mixes well with sorghum and dry cassava to give excellent food.

Crop improvement

Finger millet breeding in Uganda is perhaps as old as the crop itself. The practice of selecting and preserving phenotypically attractive panicles to form the next season's seed is common among peasant farmers. Prior to 1965, breeders had introduced and tested a number of local materials at Serere Research Station for yield, disease resistance and other desirable characteristics.

In 1965, the United States Agency for International Development (USAID) and Agricultural Research Services (ARS) of the U.S. Department of Agriculture initiated a comprehensive program with the co-operation of the then East African Agriculture and Forestry Research Organisation (EAAFRO) for the improvement of maize, sorghum and millets in East Africa. The millet breeding work was centred at Serere Research Station. This was the beginning of proper finger millet breeding work in the country.

Presently the major objectives of the finger-millet-breeding program are:

1. To develop high yielding varieties resistant to blast, lodging and virus diseases;
2. To establish a genetically broad-based population and improve it using population-breeding methods;
3. To develop varieties with short maturity and high yield for marginal-rainfall areas of Uganda;

---

*Millet Breeder and Head of Millets Section, UAFRO, Sorghum and Millets Unit, Serere Research Station, P.O. Soroti, Uganda.

4. To assemble large collections from centres of diversity in Uganda and other parts of East Africa;

5. To evaluate the improved varieties in as many environments as possible to assess their performance, adaptability and suitability for recommendation to farmers in Uganda.

Introduction has not played a very significant role in the improvement of finger millet since the crop has been grown here for over 3,000 years, and also the exotic introductions are poorly adapted. However, building up of finger millet germplasm from both exotic and indigenous collection is a necessary step in providing future breeding materials.

Currently we are growing 712 locally assembled strains and 1,242 exotic ones. Mass and pure-line selection methods have been widely used to isolate good strains and this has resulted in the restricted release of some of the national varieties such as Engeny, Gulu E, Eding, Okiring, Serere 1 and variety P 224. There are over 24 promising varieties in the pipeline.

With estimates of less than 1% natural outcrossing in this crop, and extremely small flowers which are difficult to manipulate, a number of crossing techniques, e.g. contact, hand and hot-water emasculation, have had to be tested. The last method, being easy and fast, is being used at Serere. We use 52°C for two minutes.

The success of seed set on emasculated or male-sterile panicles depends on stigma receptivity, the time of day at pollination, and prevailing weather conditions. Both stigma receptivity and pollen viability are very short in finger millet, lasting between 10 and 15 minutes. A study carried out at Serere indicated that the best time to pollinate was four days after flowering started and between 7 and 9 a.m.

Male sterility

The population used has continued to provide good steriles for crossing directly with local lines and exotics. Considerable progress has been made in seed-set on steriles and plant stature, but progress is fairly slow in the case of lowering days to flower and plant height.

Results obtained from F1 performance tests show a good expression of heterosis. Due to improved seed set-in the steriles it is now possible to have sufficient seed for hybrid trials to evaluate general and specific combining ability.

Early maturity

Finger millet varieties with early maturity have high potential in areas of low and uncertain rainfall, and can be grown during the shorter and lighter second rains between August and October. Attempts are being made to develop varieties with short maturity periods and high tillering capacities. In 1983, 361 F_3 selections from crosses between steriles and selected world-collection early-maturing entries were planted for further selection. Forty F_3 selections from crosses between Indian collections and testers were also planted for further selections. Selected F_5s are growing during this season for further selection.

White-seeded varieties

The white finger millet varieties are attractive for food and have a high malting quality for brewing, in addition to high yield. The white-seeded finger millet varieties introduced from Ethiopia and India are poorly adapted and susceptible to blast and virus diseases. The Indian varieties, being shorter, are resistant to lodging. A number of crosses have been made since 1973. Selection has been for high tillering white-seeded segregants, showing resistance to lodging and blast. Forty-three F_4s possessing combinations of these traits have been planted for further selection this year.

Trials and nurseries

Sixty-four F_1 crosses made from local high-yielding parents on steriles were grown in two-row plots using an 8 x 8 quadruple-lattice design in the first rains of 1984. Those which combined well were U 17 P 2, Gulu E P 16, Eding P 14, Serere Cross 3 P1, P226 P 28, Eding P 9, P 224 Sibs P 6, and Serere 1-2. Eighty-one disease-resistant local finger millets were also yield tested in a 9 x 9 triple-lattice design. P 669 was significantly the best yielding entry. This year, 121 varieties selected from the world collection for earliness and 100 more for yield are being grown in 11 x 11 and 10 x 10 triple-lattice designs, respectively, for further screening at Serere.

PEARL MILLET IMPROVEMENT AT SERERE, 1965 - 1973

E. Atadan*

Pearl millet (Pennisetum americanum) is an important cereal crop in several East African countries. The crop has some features which make it attractive. It is more drought resistant than sorghum and maize, does better on more sandy soils and has good seed line vigour.

Serere farm yields average 1,600 kg/ha of grain. The crop responds well to good cultural and fertilizer practices, then giving up to 2,500 kg/ha. Before the 1980s, the crop was not plagued by insects and diseases in East Africa. Its most serious disease was ergot caused by Sphacelia. However, the disease is not serious under the low-rainfall conditions where the crop is usually grown.

Breeding

In Uganda, the broad breeding objectives have been and will continue to be to develop and distribute genotypes capable of producing high stable yields with good grain quality.

As with any other crop, a high and continuous inflow of new variability is essential in order to achieve continuous progress in the breeding program. At Serere, as early as 1965, local and introduced varieties had been grown and observed by breeders under the Uganda Department of Agriculture.

The most important introduction was Zuarungu variety from West Africa. It had a large grain and yielded more than the local types. Six strains were developed by mass selection. Inbreds of these were crossed to steriles from the USA (Tift 23, 241, 239, and 238) to indentify fertility-restoring lines. The same was done to 12 local Serere lines.

In 1965, 2,100 lines from Indian collections were obtained through the courtesy of Dr. Kenneth O. Rachie of the Rockefeller Foundation, New Delhi. Then, in 1968, 45 new introductions from Ethiopia were brought by Dr. LeRoy V. Peters and were added to the germplasm holding at Serere. Following the Zuarungu variety, late-maturing types, such as Samaru from West Africa were introduced in 1969.

---

*Senior Assistant Agricultural Officer (Research), UAFRO, Sorghum and Millets Research Unit, Serere Research Station, P.O. Soroti, Uganda.

Maintenance of germplasm has been done through selfing and planting in isolation blocks in the first rains each year. As the material increased, cold storage was made available, but unfortunately it broke down in 1973 and we lost a lot of material.

From 1966 to 1970 the major work on the germplasm was to classify it into fertility-restorer and non-restorer groups for use in hybrids. From a total of nearly 3,000 crosses of the accessions, it was found that 74% were restorers, 6% were non-restorers and 20% were carrying both restorer and non-restorer genes. Restorer and non-restorer populations were started in 1969 with remnant selfed seeds of those plant selections which showed good heterosis with sterile-seed parents. Subsequently it was possible to have 266 selections in the restorer population and 110 in the non-restorer population. Both of these populations were intercrossed within their respective groups at least twice more before selection pressure was started.

Grain yields and other agronomic traits of Serere lines, Serere Composites, Indian Bajra Hybrid No.1, and introductions from West Africa were evaluated at Serere in 1969. It was found that most of the West African strains took at least two weeks longer to mature than the East African types and their yields were greatly reduced due to lack of moisture during the early part of the growing season. After the first cycle of selection, Composite 1 was the top entry in the test.

In 1968, mass selection was started for bristle and non-bristle populations. In 1969, five new ones were included. The specific characteristics of those five were maturity period, height, head size and head types. These populations formed a major nucleus of our breeding programme. By 1973, we had organized 14 populations by using the recurrent-selection method. The dwarf population (Serere 31) and late-maturing population were composed mainly of local Serere material and West African materials, respectively.

Evaluation of all the populations started at Serere and two other sites in the northern region. Serere Composites 1 and 2, the non-bristle and bristle types, were outstanding in giving consistently high yields in most sites and were, therefore, recommended for commercial production. Composite 1 was sent to four low-rainfall areas in Tanzania for demonstration in farmers' fields. Composite 2, known as "Ugandi" in Sudan, is now popular there.

Lodging is a problem in pearl millet, therefore, reduction of height is desirable. All the strains used in East Africa are tall (2-3 m), depending on soil moisture and fertility, and tend to lodge. In 1965 Serere inbreds of Zuarungu types from West Africa were crossed to Tift 238, a dwarf variety from the U.S.A., thus introducing d_2d_2 (dwarf) genes of U.S.A. selections.

Protein-quality studies of 24 pearl millet selections from Serere Composite 1, an outstanding yielder, were made by sending them to USAID/ARS cereal laboratory in 1973. The protein level of these samples ranged from 10.8 to 14.5% and the lysine index from 0.25 to 0.31 % of sample. Further studies could not be made due to shortages of staff which had arisen by then.

The bird problem

Damage by birds such as Quelea, sparrows, weavers and doves has greatly hindered the production of pearl millet in many areas of East Africa. Even those areas which produce it have had their quality and quantity so adversely affected that production now remains in the hands of farmers who can afford the manpower to scare birds away from their fields.

Intensive campaigns were mounted in East Africa to kill the Quelea with chemicals and explosives in the hope that the same degree of success achieved in the control of locusts in East Africa would be realized. There has not been much success so far. At Serere, in 1970, two hectares of the bristled SC 2 were planted next to two hectares of the non-bristle type in an area which was little disturbed by people in order to assess bird damage. It was observed that birds went for the non-bristle type first and then resorted to the bristle type when the non-bristle type was almost finished. It was noted that the bristles were not stiff enough or long enough to scare birds. Now, more bristled materials are being incorporated into our Composites.

Regional testing

Under the defunct East African Community, regional variety testing of pearl millet started in 1966 by comparing the performance of a number of hybrids relative to their pollinators. In general, hybrids out-yielded the pollinators in most tests.

Though hybrids have persistently outyielded composites, the need to supply seed for planting each season has hindered their use in Uganda at present. Composites are being used as they can be grown for about five years before showing some yield decrease due to inbreeding. By that time breeders are able to supply fresh seed.

The departure of Asians fom Uganda in 1972 reduced the demand for pearl millet and hence production fell. Now Karamoja produces and consumes 95% of the crop in Uganda. As the Asians have begun returning to the country, the crop has a better future. Hence research on the crop, which was reduced to mere maintenance in 1973, resumed with greater effort in 1976.

THE PRESENT STATUS OF PEARL MILLET BREEDING AT SERERE

Sam E. Odelle*

Research work on pearl millet at Serere was drastically reduced after the change in the Uganda Government of 1971. This was brought about by the lack of adequate staff and suitable facilities. The break-down of our cold-storage equipment in 1973 was responsible for the loss of germplasm viability because planting and selfing all the material every season could not be carried on for lack of paper bags. The only materials which were saved were some synthetic lines and composites. Very little regional testing of our materials could be carried out during that time for lack of facilities in the testing centres.

Active work on pearl-millet breeding resumed in 1976 following the receipt from ICRISAT of F_2 and F_3 segregating materials. The primary aims of pearl-millet at Serere are:

1. To improve early-maturing populations using recurrent selection methods;

2. To select varieties and composites resistant to lodging, stem borers and birds;

3. To assemble a large number of pearl-millet breeding materials from centres of diversity for use in the breeding programs;

4. To continue to evaluate improved composites over several locations in the low-rainfall and poor-soil areas of Uganda in order to identify suitable genotypes for release to farmers.

Nine composites and 16 synthetics were saved and carried over from the previous breeding work at Serere. These were added to the segregating materials received from ICRISAT. Some germplasm expeditions were made last year in the north, east and western Uganda and resulted in some 23 collections.

Following the loss of some of the composites, efforts are now being made to develop more composites by recurrent selection. Some materials that come from open pollinated heads from the planting of Indian segregating materials were harvested and 120 heads selected and put together for recombination. These have

---

*UAFRO, Sorghum and Millets Research Unit, Serere Research Station, P.O. Soroti, Uganda.

been planted in isolation and next season selfing is expected followed by S_1 testing. This material appears particularly promising because of its profuse basal tillering compact heads.

Another composite being developed comes from the material which was in the International Pearl Millet Adaptation Trial sent by ICRISAT in 1981. Most of the entries gave good yields. Though some of the entries were actually constituted from Serere material, most of the entries were of Indian origin.

Tests have shown that the yields of our composites have tended to decline, which may be due to the narrowing of our genetic diversity and subsequent inbreeding depression. Efforts are under way to widen the genetic base of our composites. Agronomic data for 34 entries grown at Serere in the second rains of 1982 are given in Table 1.

Table 1. Agronomic data for 34 entries grown at Serere, 1982 second rains.

Identification	Rank of grain (wt)	Grain wt (q/ha)	Days to flower	Plant height, (cm)
Set II Recombination	28	22.4	57	205
Serere 46	20	26.5	56	220
Serere Composite 14	18	27.5	56	210
Serere Composite 13	20	26.5	57	215
Serere 39	27	23.0	56	205
Casady's Dwarf Pop.	31	20.5	54	215
Serere 6A	10	34.0	57	215
Serere Composite 4	31	20.5	56	225
ICRISAT Recombination	25	23.5	55	225
Serere 40	25	23.5	54	210
Serere 42	2	40.5	54	220
Serere 30	18	27.5	55	215
Serere 10LA	5	37.0	54	205
Serere Composite 3M	5	37.0	55	210
Serere 44	14	32.5	54	200
Serere 49	7	36.0	55	210
Serere Composite 2	8	35.0	55	220
Set 1 E3	3	40.0	55	220
Serere 34	31	20.5	57	220
Vincent's Dwarf	23	26.0	55	220
Serere 17	14	32.5	58	235
Indian	4	38.0	56	210
Serere 10LB	16	29.0	55	220
Serere 33	12	33.0	54	205
Serere 50	20	26.5	53	205
Serere 38	1	41.5	55	205
Serere Composite 10	8	35.0	52	210
Set II E43	23	22.5	57	210
Set III Recombination	10	34.0	56	215
Serere Composite 1(S)	30	21.0	54	210
Serere Composite 4M	16	28.5	54	205
Serere 2A	34	16.5	58	220
Serere 45	28	22.0	54	205
Serere Composite I	12	33.0	57	210
Mean		29.5	55	213
L.S.D.		4.0	8.8	19.7
CV, %		53	10	7

SORGHUM BREEDING IN UGANDA

Vincent Makumbi Zake*

Sorghum improvement in Uganda was started in the late 1930s with sorghum collections and introduction. Earnest breeding work was begun in 1954. Yet the problems breeders face today have not changed much since then as shootfly, birds, low grain yield and quality still command a high priority in our program. Nevertheless, high-yielding, lodging-resistant, improved varieties that persistently outyielded the local ones over a wide range of environments were obtained and released to farmers. These varieties include Serena, Seredo, Lulu, and 2K x 17/B/1. In the early years evaluations for wide adaptation and stability were carried out through many testing sites scattered in East Africa.

Presently in Uganda, the existing variety trial centers which are individually operated by variety-trial observers, offer an opportunity for testing and selection for broad adaptation and disease and pest resistance. However, over the years, the level of performance of the trial centers has declined. The observers have not been able to attend the pre-season workshops on results and plans which are held at Serere, as regularly as is necessary. Regular visits by the research station scientists to the trial sites have also declined because of financial constraints. In these circumstances the data received from the trial centers cannot be viewed as completely reliable. It is hoped that the rehabilitation of the trial centers will enhance our research output.

Introduced trials and observations

The East African Co-operative Sorghum Regional Trials for 1985 were received for growing this season in Uganda. The High/Intermediate Elevation Trial was sent to Kalyengyere in Kigezi District. The Very Dry Lowlands Trial was sent to Moroto and Kotido, while the Low Elevation Trial was sent to Ngetta. At Serere, one Low Elevation Trial and the Eastern Africa Cooperative Sorghum Screening Nursery have been planted. Thirty eight progeny rows received from ICRISAT have also been planted.

***Principal Research Officer-in-Charge, UAFRO, Sorghum and Millets Unit, Serere Research Unit, Serere Research Station, P.O. Soroti, Uganda.**

Development of drought escaping and tolerant varieties

This program was continued in order to develop drought escaping or tolerant varieties and hybrids that would be useful in drought -prone areas of Karamoja where rainfall is unreliable. It is our observation that many of the standard Serere varieties are caught in moisture stress at the flowering stage when grown in Karamoja. Varieties and hybrids with shorter maturity periods are expected to have higher potential and reliability. Early maturing and drought-tolerant source lines have been crossed with drought-escaping derivatives of 3K x s and 7Z x s developed at Serere. A 6 x 6 triple-lattice trial consisting of 3K x, 7Z x and 0Z x early maturing derivatives was grown this season at Serere and Kotido for screening.

In addition to selection based on early maturity and drought tolerance, high tillering and resistance to shootfly and major leaf diseases are also being considered. All grains are brown seeded and plants are resistant to lodging. Further infusion of early maturity and drought-tolerant genes will be increased this season by incorporating SB65 and Simila which are early flowering and have good combining ability. Gambella 1107, Melkamash 79, Urumimbi and 76 T1-23 from the Eastern Africa Regional Trials will be incorporated into our crossing programs. It is our intention that F_2s will be grown in appropriate areas of Karamoja for selection of suitable materials.

District variety trials

Testing of experimental lines and hybrids from the breeding programs over a wide range of environments was done in order to evaluate their performance and adaptability with the objective of identifying suitable varieties for release to farmers. In 1984, results of the performance of 24 varieties and hybrids were received from only three sites (Table1). The entries which gave 30 q/ha or more were Kafirnum A x SB65, Kafirnum A x Simila, 9DX 8/F_5/31, SB65, Seredo, ES25 Ht.Red., and 9DX 5/F_5/34. It was observed that earlier-flowering entries performed comparatively better than the late-flowering ones.

Development of high-altitude sorghums

It is estimated that half of the total production of sorghum in Uganda is produced and consumed in Kigezi and Karamoja. In Kigezi, which is a high-altitude area, sorghum assumed great importance in the mid-1930s probably due to finger millet's higher labor requirement and greater sensitivity to declining soil fertility under conditions of land pressure and rainfall distribution.

Table 1. Grain yield (q/ha), plant height (cm) and days to flower of 24 sorghum varieties grown at three sites during first rains, 1984.

Entry	Grain yield			Mean		
	Serere I	Serere II	Kabera-maido	Yield	Plant height (cm)	Days to flower
9DX 5/F5/34	47	28	15	30	158	63
9DX 8F5/31	42	41	19	34	132	61
9DX 7/F5/11	36	22	9	22	124	66
SB 65	44	37	17	33	115	55
2kx 17/97-103	29	28	7	21	163	66
2kx 17/B/1	25	28	13	22	142	64
4MX 35/41	43	30	9	27	113	66
4MX 35/30	30	30	7	22	155	65
4MX 37/101	27	27	12	22	133	62
4MX 11/9/1	24	19	9	17	156	70
4MX 11/10	40	28	9	26	158	68
4MX 11/9/2	35	19	9	21	152	65
4MX 37/100	31	28	8	22	141	66
4MX 11/8	31	26	14	24	133	66
4MX 37/97	26	13	8	16	135	67
4MX 11/9/3	30	18	9	19	161	67
4MX 35/40	23	25	10	19	98	62
Kafirnum A x Simila	40	45	21	35	183	56
Kafirnum A x Lulu D	25	41	9	25	132	59
Kafirnum A x SB 65	43	42	24	36	154	55
Serena	36	32	19	29	138	58
Seredo	48	34	15	32	137	61
E 525 Ht.Red.	32	39	19	30	144	61
Simila	38	30	16	28	129	61
Mean	34	30	13	20.4	141	63
LSD (P=0.05)	16	6.2	7			
CV%	29.4	10.95	46.2			

Sorghum is an important staple in the drier parts of Kigezi. Utilizing high-altitude sorghum locally available from Uganda and introductions from Ethiopia and elsewhere, the high-altitude breeding program is emphasizing cold tolerance, early maturity and drought tolerance, in addition to improved grain yield. Early generation segregating materials will be grown at one of the trial centres situated in drier and colder parts of Kigezi.

Hybrid improvement

Several male steriles have been developed at Serere with the objective of finding an adapted high-yielding, shootfly-resistant and high tillering male-steriles. The three most promising locally developed male steriles are Kafirnum A, 7DMS 7A and 8MSC 1A. CK60A is the female parent of all the recommended sorghum hybrids in East Africa, but it is extremely susceptible to shootfly.

Ethiopian high-altitude sorghums which were collected by Dr. Mukuru in 1975 have been found to have good combining ability with Serere materials. Besides, many have thick stems which render them resistant to lodging. However, they are late flowering, especially at higher elevations, and are susceptible to leaf diseases. Promising Ethiopian materials were selected and crossed to CK60A and 87/2DMS 1A male steriles. High-yielding and early flowering hybrids were obtained with CK60A male steriles. The hybrids of 87/2DMS 1A male sterile were shorter than those of CK60A. The best combiners and early flowering ones have been crossed in diallel with early maturing Serere entries and Kigezi high-altitude materials to develop materials suitable for the highlands of Kigezi.

THE EFFECT OF CONTINUOUS CULTIVATION ON THE YIELDS OF FINGER MILLET, PEARL MILLET AND SORGHUM UNDER SYSTEMS OF ANNUAL AND ROTATIONAL CROPPING AT SERERE

F.X. Koma-Alimu*

In his study of farming systems of Uganda, Parsons (1960) found that shifting cultivation was a major feature in fertility regeneration in most parts of the country, and especially in the northern Region. However, even at that time, continuous cultivation of land was known, especially in the montane system. Today, population growth is putting increasing pressure on land such that, in most areas, fallowing periods are being drastically reduced, or even eliminated altogether. Cultivating without resting the land is practised in the Districts of Kabale, Nebbi and Kumi. A recent farming-systems survey (unpublished) of Soroti and Kumi Districts by the Serere Research Station team confirmed the increasing pressure on the land. This practice has obvious deleterious effects on the productivity of the soil, especially as few farmers use artificial fertilizers and the use of compost or farmyard manure is limited.

Norman (1979) pointed out that intensive cropping of land resulted in nutrient depletion. Dennison (1961), and Nye and Greenland (1960) showed drastic reductions in finger-millet yield from 920 kg/ha to 330 kg/ha and sorghum yield from 540 kg/ha to 90 kg/ha in a period of 25 years. Mouttapa (1974) reported that in Senegal, where rainfall was high, semi-intensive cultivation caused drastic nutrient depletion in a period of 90 years. Carbon content dropped from 16.5% to 5% in forestland after that period of cultivation. Other decreases were: 0.9% to 0.33% for soil nitrogen; 5M e.g./100g to 1.OM e.g./100g for calcium; 1.7M e.g./100g to 0.5M e.g./100g for magnesium; and 0.7M e.g./100g to 0.4M e.g./100g for potassium. However, Djokoto and Stephens (1961a, 1961b) concluded that in high-rainfall areas, only phosphorus and potassium were limiting factors and in lower rainfall areas nitrogen and phosphorus were limiting for cereals. Therefore, the need to initiate research programs to determine ways of sustaining soil productivity, cannot be overemphasized. Improvement and maintenance of the soil fertility level is vital. This study was designed in order to observe the effects of mineral fertilizers on soil under rotational and mono-cropping systems.

*Soil Chemist, Serere Research Station, P.O. Soroti, Uganda.

Materials and methods

The experiment was designed by McWalter and Wimble in 1966. The objective was to investigate the possibility of continuously cultivating the land while attempts were made to sustain soil-nutrient levels by means of mineral fertilizer applications. The trial was sited at Serere Research Station, 1^{O} 31'N and 32^{O} 27'E, at about 1,180 meters altitude. The rainfall, which is bi-modally distributed, with peaks in April/May and August/September, averages 1,380mm annually. The soil is rather shallow, highly leached ferallitic oxisol overlying laterites.

A number of commonly grown crops were chosen for cultivation under two systems: growing one crop annually or combining two short-term crops, and cultivating under a suitable combination of all crops involved, based on farmers' common rotation of them. These were cotton, variety SATU; finger millet, variety Engeny; sorghum, variety Serena; pearl millet, variety Serere Composite 2; and groundnuts, variety B 1. In the rotation system, cotton was grown alone in one year, finger millet was grown in the first rains, pearl millet in the second rains of the second year, and groundnuts in the first rains, and sorghum in the second rains of the last year in the rotation cycle. The same crop combinations were made in the non-rotational treatments. The treatment combination is as shown in Table 1.

Table 1. Cropping sequence and system combination in fertilizer study

Treatment number	Cropping sequence	System
1	Groundnuts/sorghum	Continuous
2	Finger millet/pearl millet	Continuous
3	Cotton	Continuous
4	Groundnuts/sorghum	Rotational
5	Finger millet/pearl millet	Rotational
6	Cotton	Rotational

Each treatment was in two strips, each split into five subplots at harvest to make ten replicate harvests per treatment. All crops were planted and maintained under recommended agronomic practices.

To maintain the soil nutrient levels in phosphorus, potassium and nitrogen, 200 kg/ha each of SSP and CAN and 150 kg/ha of muriate of potash were applied annually. SSP and KCL were broadcast and harrowed in before planting. CAN was applied by top-dressing three weeks after planting. These were modified by applying 200 kg/ha of a 25: 5:5 fertilizer from 1982 onwards when the previously used fertilizers were not available. No direct nitrogen fertilizer was given to groundnuts. Apart from calcium, sulphur and magnesium as impurities from SSP, no supplementary fertilizers were given to supply the rest of the nutrient elements being depleted. This was because they were not available. No compost or animal-enclosure manure was applied.

The main trait measured in these experiments was yield trend for each cropping system. Other factors of importance were qualitatively noted and treated as extraneous. These included rate of germination, vigour, deficiency symptoms, weeds, pests and disease incidence. This report lays emphasis on yield trends. The results reported in this paper are only for finger millet, sorghum, and pearl millet.

Results and discussion

The main features of the results are presented in Table 2. It is evident that in all three crops there was a general trend of yield decrease within some years of first breaking the land. This was most pronounced in the case of finger millet (Figs. 1, 2 and 3), especially the annually grown crop. The difference between the rotationally- and annually-grown crop was highly significant.

The high coefficient of variation between the years was mainly due to external factors. For finger millet, especially in continuously grown plots, there was a heavy build-up of weeds of the same or similar genera, such as Eleusine spp. and Setaria whereas in the rotational plots these were diluted with Cynodon and Amaranthus and other broad-leaved weeds, easily distinguishable from the crop at thinning. Competition for nutrients apart, the weeds of Eleusine and Setaria are too difficult to distinguish at thinning. The seed build-up of these weeds had become so much that attempts to plough several times, allowing the weeds to germinate first each time, did not noticeably reduce the weed population in 1977 and 1978. The better stand of finger millet in the rotation system was due to this factor, and the fact that the weeds were destroyed before seeding when crops other than finger millet were grown. In the continuously grown millet, the germination rate of the weeds was so high that, although the crops were planted in rows, these became indistinguishable long before normal weeding time.

Table 2 : Mean yield, kg/ha, of ten plots cereals crops in continuous and rotation system grown at Serere, 1967 - 1983

	FINGER MILLET			PEARL MILLET			SORGHUM		
Years	Continuous	Rotation	Mean	Continuous	Rotation	Mean	Continuous	Rotation	Mean
1967	3859	3482	3670	2861	2366	2613	1800	1549	1674
1968	3903	4380	4141	1971	2457	2214	4563	4203	4383
1969	2838	3626	3232	2344	2383	2363	3384	3133	3258
1970	1379	3235	2307	1776	1745	1760	3979	3789	3884
1971	3350	1434	892	2418	2266	2342	4925	5028	4976
1972	526	1885	1205	2680	2386	2533	4163	3940	4051
1973	54	530	292	-	-	-	-	-	-
1974	145	920	532	589	624	605	6321	6364	6337
1975	146	1440	793	1726	1473	1599	1092	1068	1080
1976	195	695	445	734	873	803	1604	1764	1684
1977	220	1880	1050	126	122	124	922	915	918
1978	-	-	-	-	-	-	-	-	-
1979	-	-	-	1095	668	881	793	1332	1065
1980	484	1305	894	1910	1722	1816	-	-	-
1981	295	47	171	1404	143	773	780	995	887
1982	495	425	460	1493	1036	1264	1251	1419	1335
1983	60	1210	630	860	477	678	-	-	-
MEAN	940	1718	1329	1589	1382	1486	2645	2644	2646
L.S.D.		651			1151				462
C.V., between years		48%			78%				16%

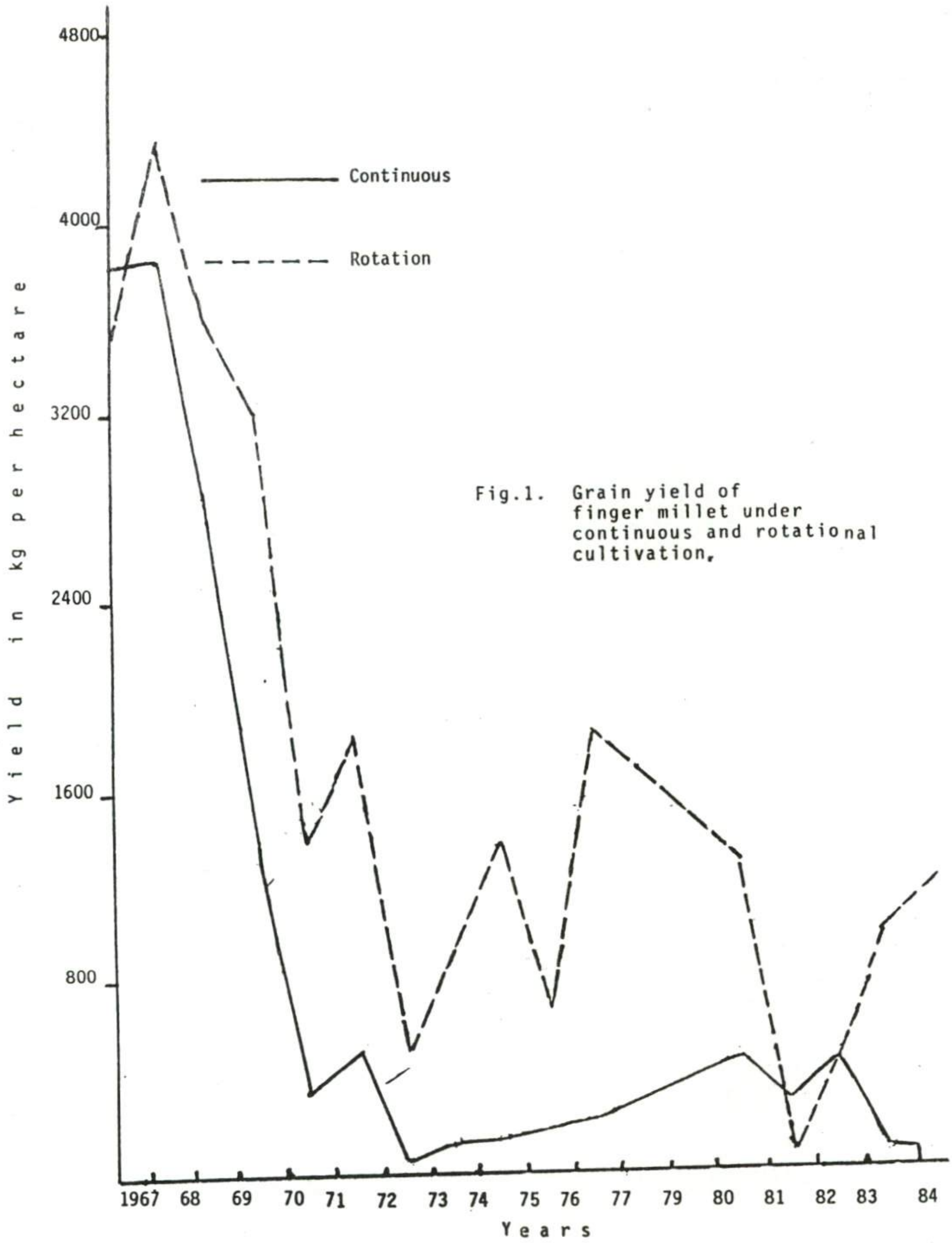

Fig.1. Grain yield of finger millet under continuous and rotational cultivation.

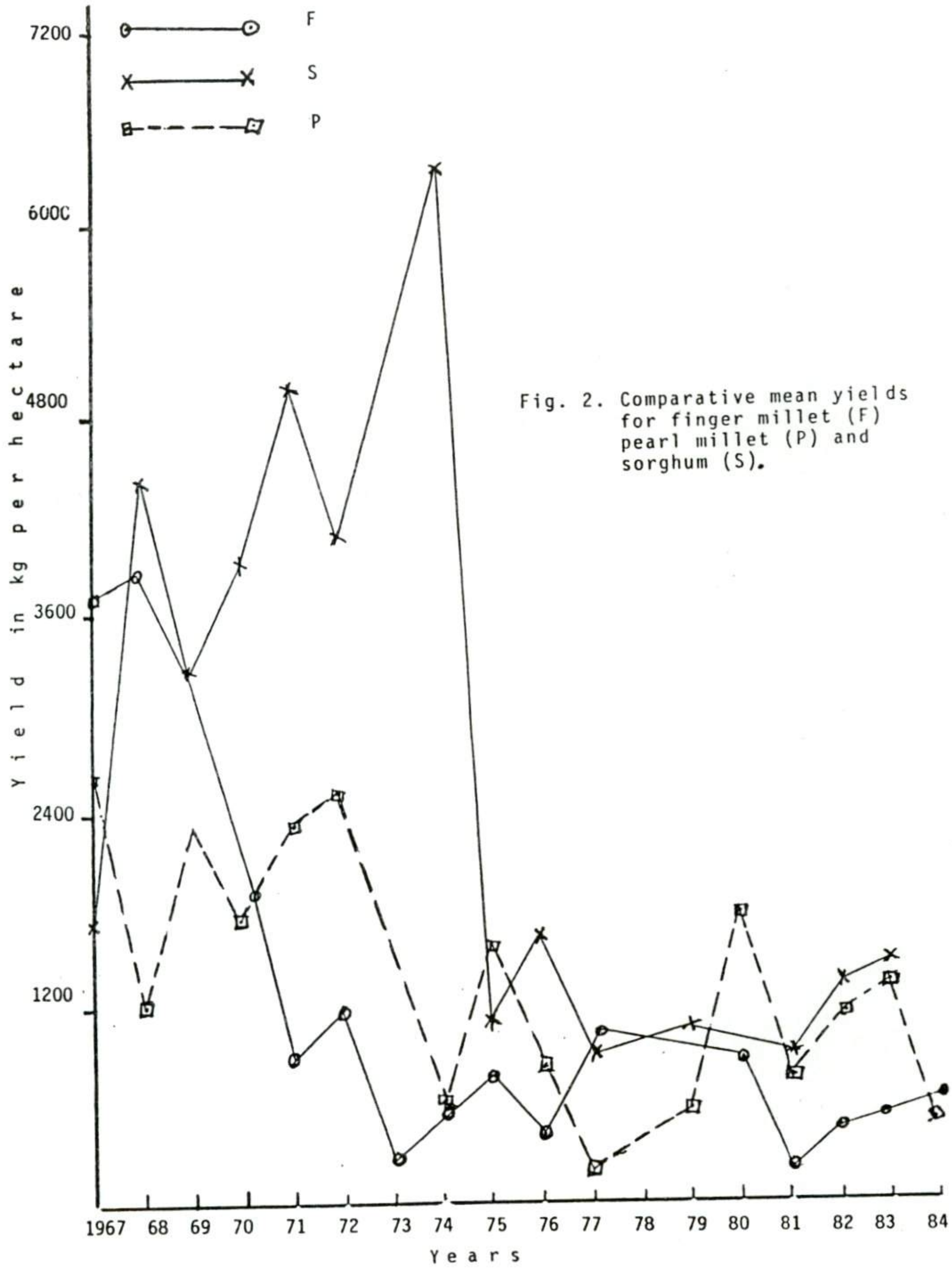

Fig. 2. Comparative mean yields for finger millet (F) pearl millet (P) and sorghum (S).

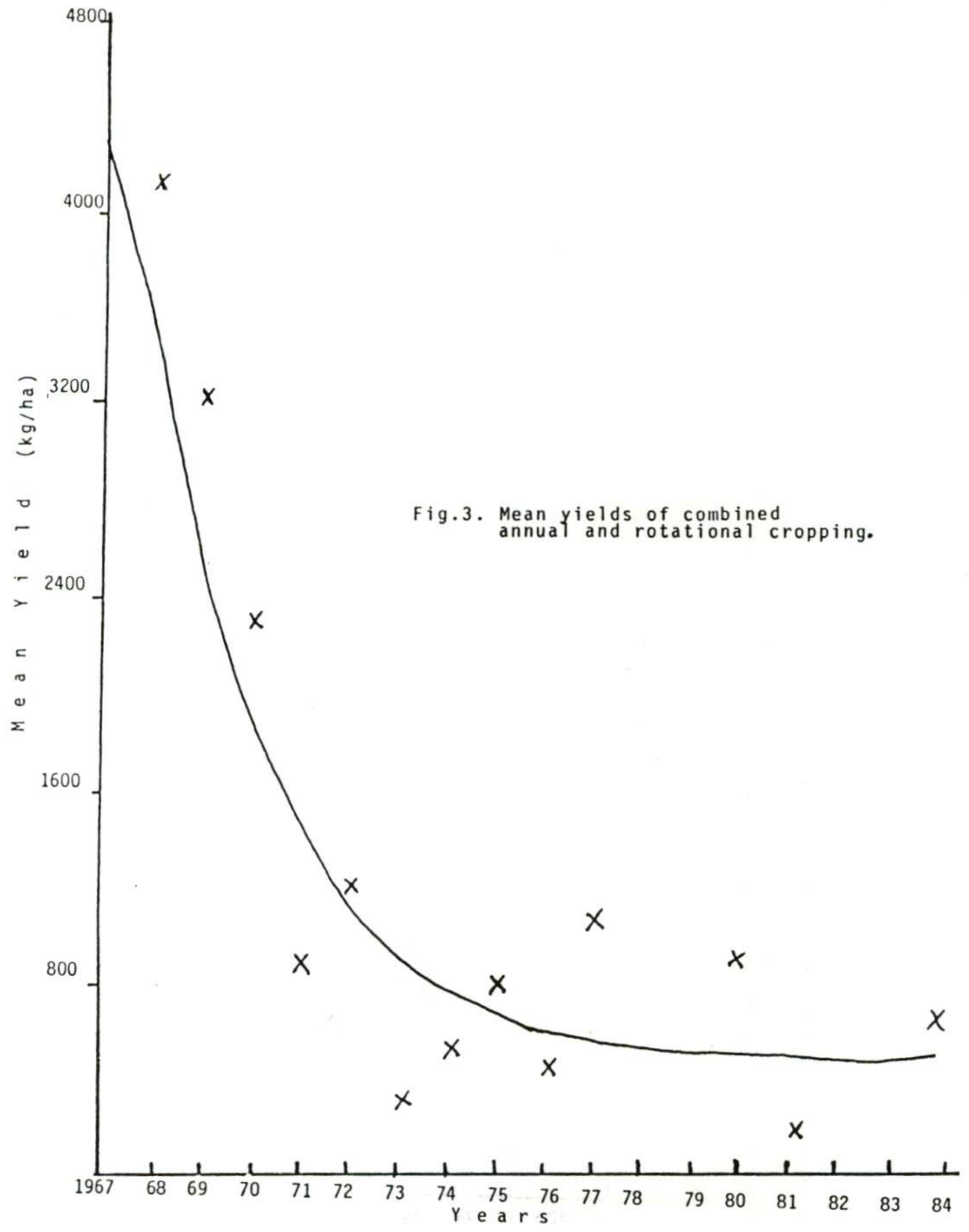

Fig.3. Mean yields of combined annual and rotational cropping.

The yield trend for pearl millet was also clearly on the decrease (Figs. 2, 4, and 5). The very high coefficient of variation or fluctuation of yield in these years is due to a number of factors. In some years, (1974, 1977) germination was poor due to faulty machine planter. Gap-filling damage on this crop is always very high, but varies from year to year.

The cotton stainer has become a serious pest, sucking the ovaries dry at flowering. No control measures were taken against it as the relevant insecticide is toxic to humans. It is interesting to note that the continuously-grown pearl millet gave a slightly higher yield than in the rotational system.

Sorghum yields did not vary between annual and rotational treatments, but the general decrease in overall yields is clearly shown in Figs. 2, 6 and 7. For this crop, the most important extraneous factors were pests and diseases. Stem-borer, shootfly and smut became more and more common. In certain years, too much rain at flowering or sudden setting with drought were the main reasons for poor yield. Bird damage was satisfactorily controlled. Otherwise the general agronomic appearance of the sorghum crop was promising, given good weather conditions and control of pests.

The yield decrease must, therefore, be attributed to nutrient depletion other than sodium, phosphorus and potassium. The effect of decreasing organic matter, calcium and magnesium has already been mentioned (Mouttapa, 1974). Other nutrient elements not mentioned must also be declining. The "law of the minimum" would ultimately apply. Norman (1979) suggested constant manuring, inclusion of mineral fertilizers and soil-conservation management practices to off-set the effects of intensive cultivation on the fertility of the soil. McWalter (1972) recorded highly significant differences for continuous versus fallowing for pearl millet and sorghum, with high responses to N and manure, but none to SSP, after 30 years of cropping cycles in a fertility experiment. Rather than be confined to fertility aspects, long-term experiments should also be monitored by crop protectionists. It is natural that pests and diseases tend to become established when the host plants are available under continuous cropping systems. These, and weed infestation due to cropping without fallowing, may confound any fertility investigation through the yield component.

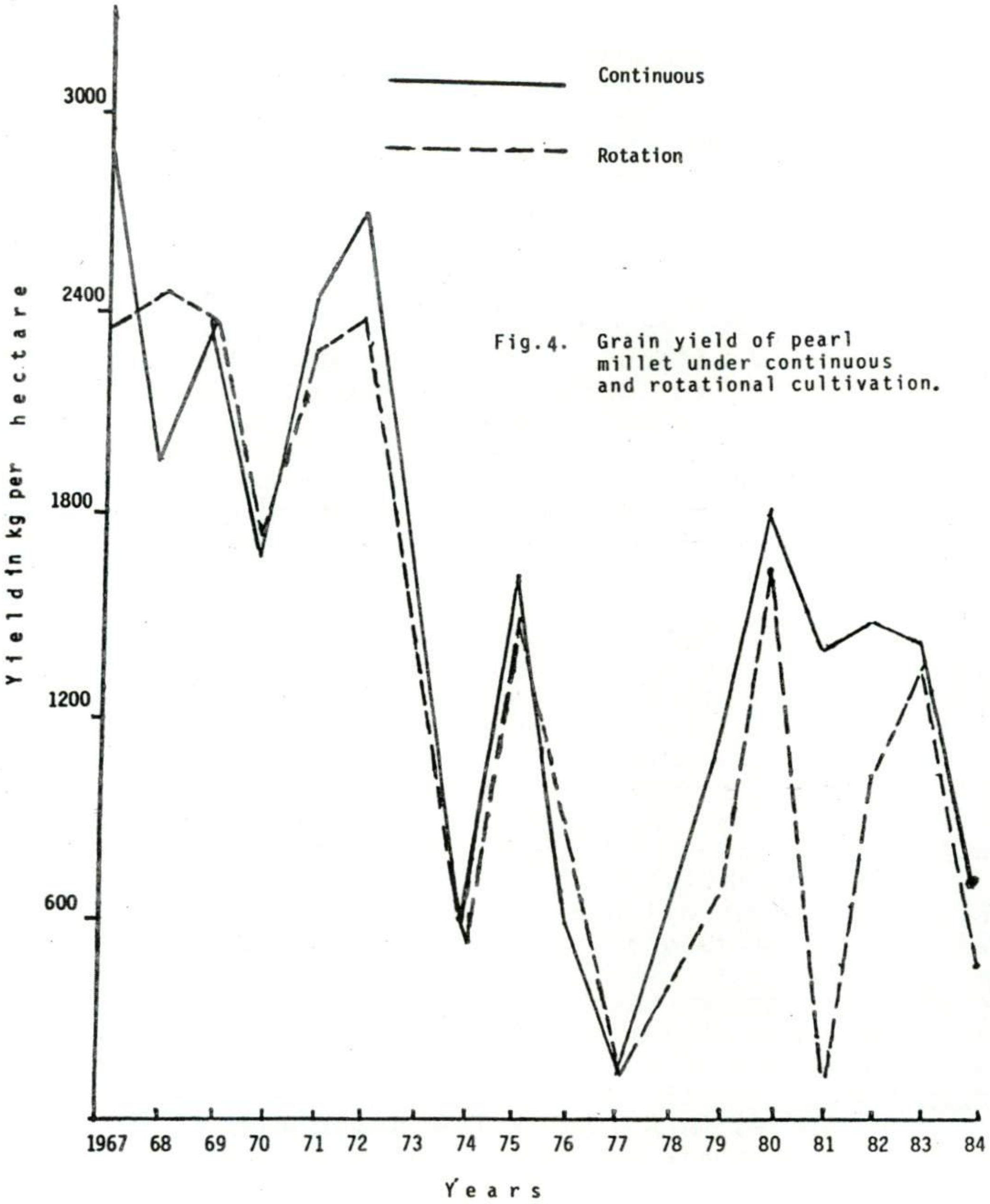

Fig. 4. Grain yield of pearl millet under continuous and rotational cultivation.

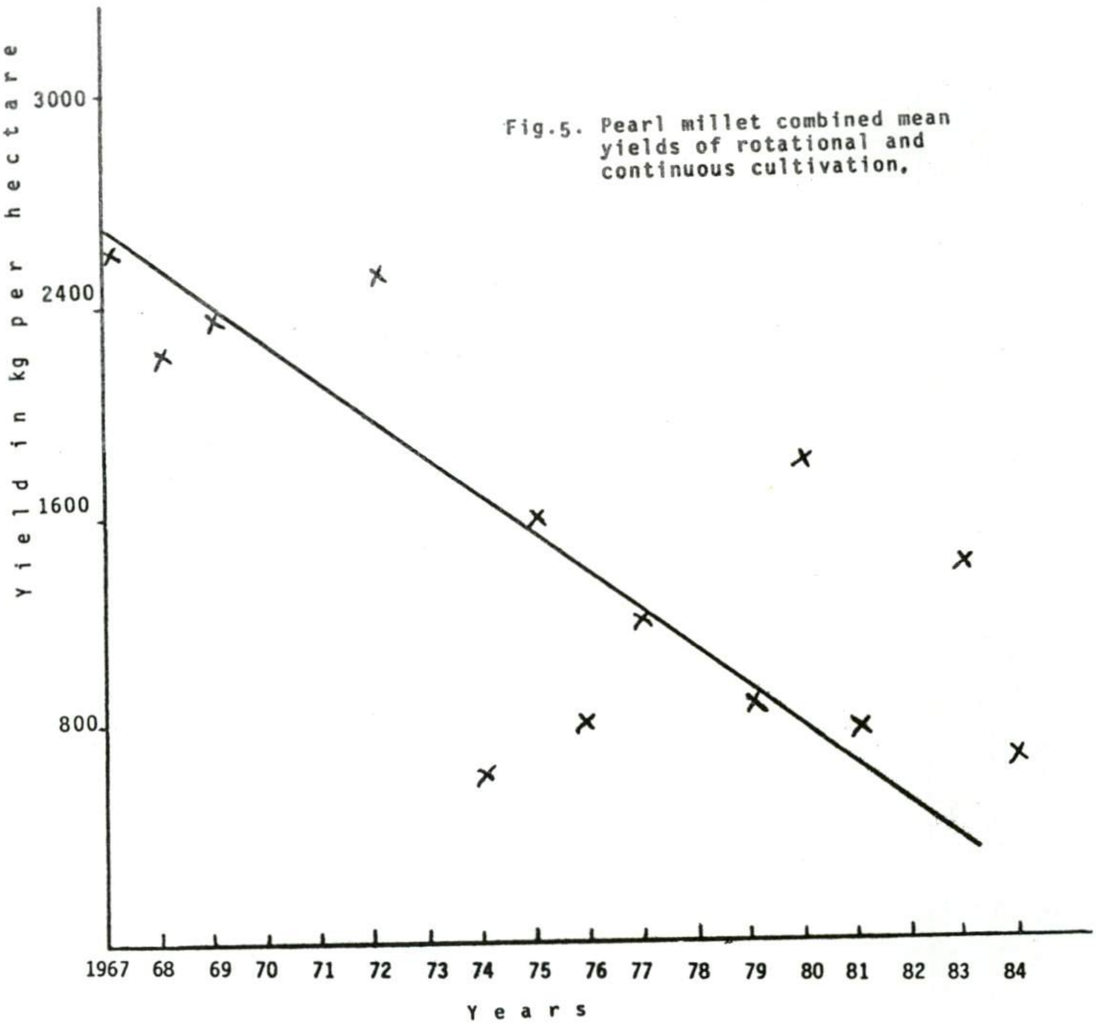

Fig.5. Pearl millet combined mean yields of rotational and continuous cultivation,

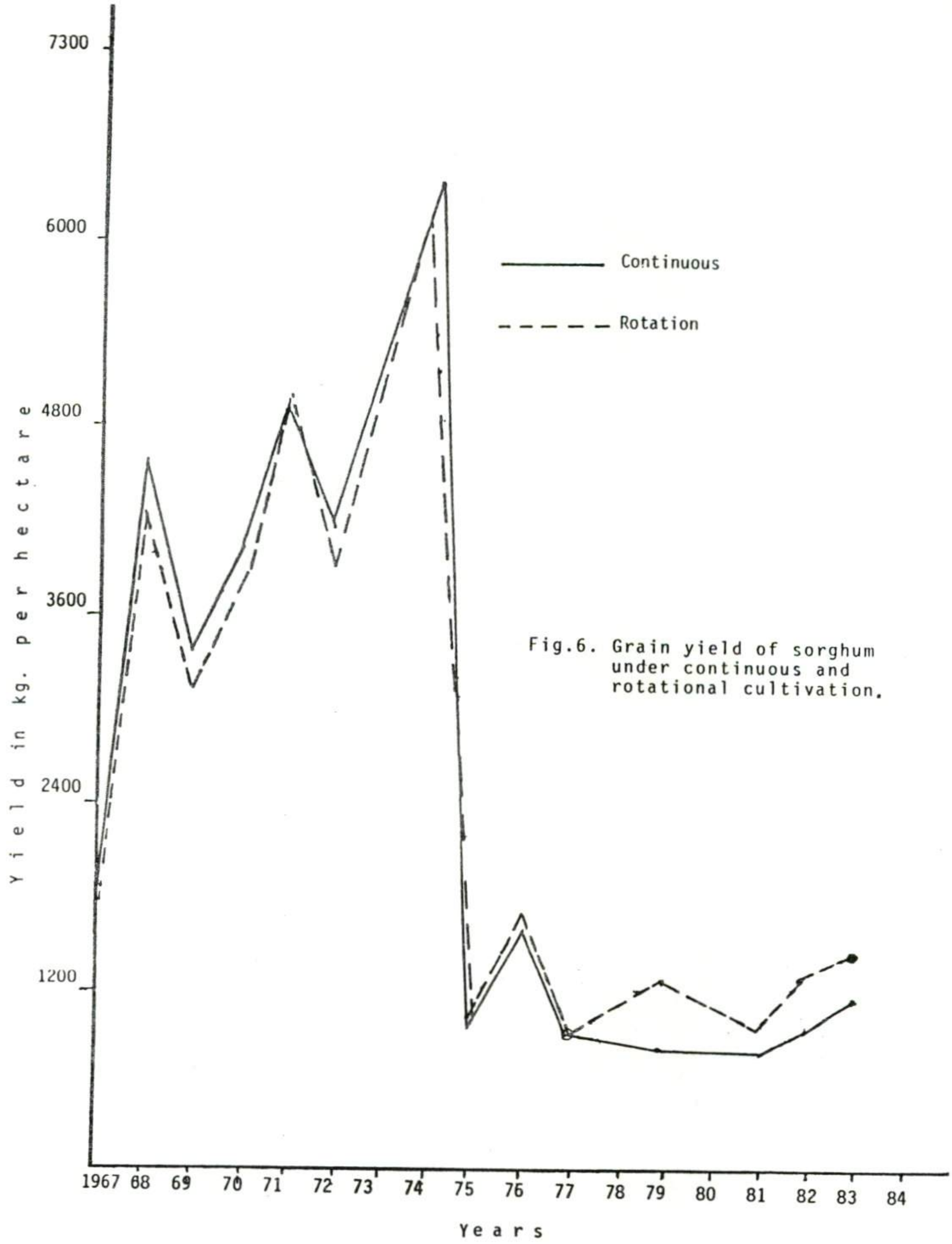

Fig.6. Grain yield of sorghum under continuous and rotational cultivation.

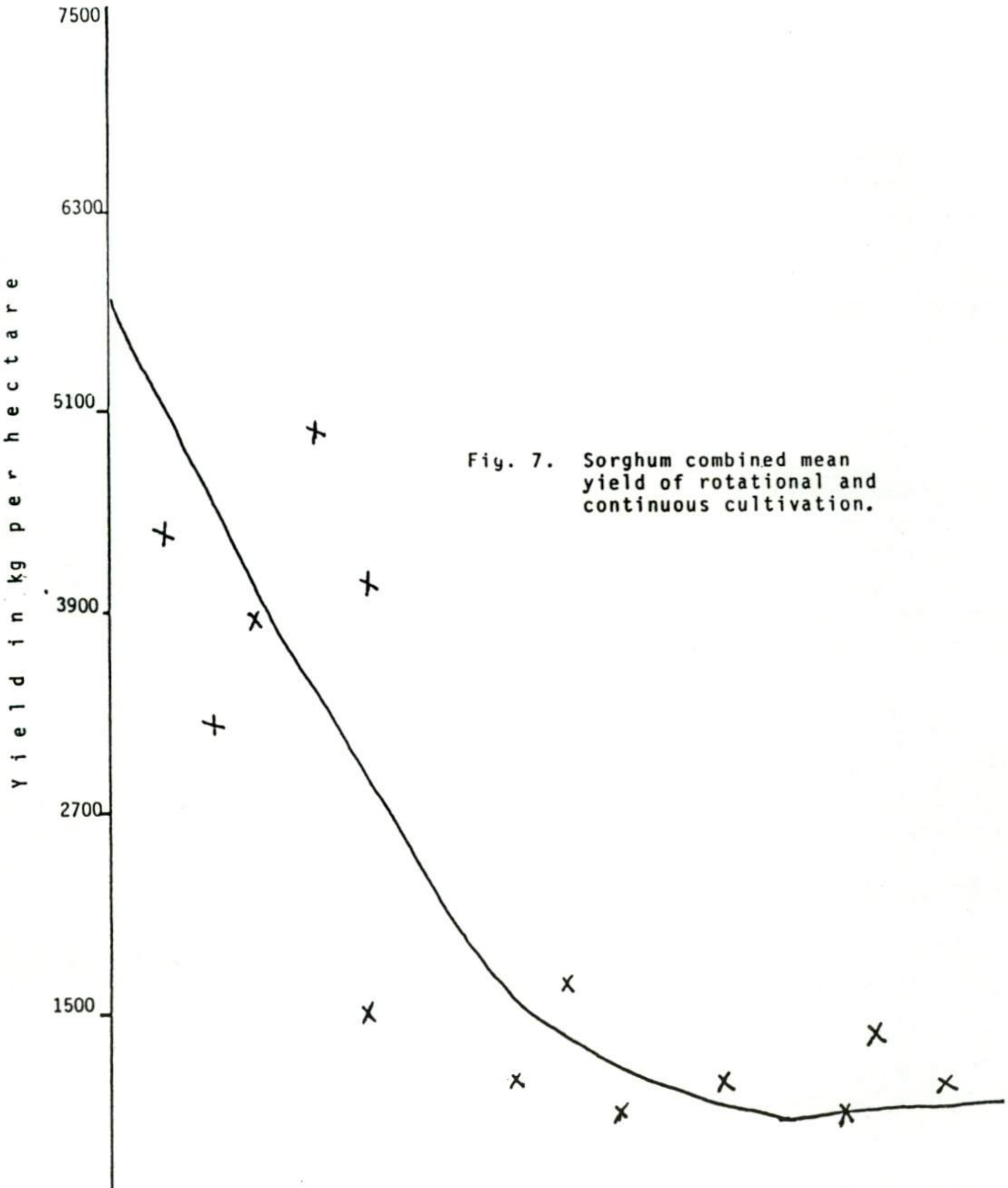

Fig. 7. Sorghum combined mean yield of rotational and continuous cultivation.

Conclusion

The system of continuously cultivating the land is on the increase in Uganda. More research programs should be geared towards maintenance of production levels under intensive tillage. Soil fertility maintenance is one of the ways. In this experiment it was found that for the cereals (sorghum, finger millet and pearl millet) even though adequate sodium, phosphorus and potassium fertilizers were applied yearly, the addition of farmyard manure may improve the declining yield trends as this is an all-nutrient source, however inadequate in some cases. Alternatively, all nutrients must be applied periodically, at least at maintenance level.

The results show that continuous annual growing of finger millet in the same field must be discouraged, mainly due to weeds similar to the crop accumulating heavy seed reserves in the soil leading to acute competition with the cultivated crop. The need to select appropriate pre-emergence but short-term-effect broad-spectrum herbicides is evident.

Continuous growing of pearl millet was slightly better than rotation with groundnuts, sorghum and cotton. There is a need to collaborate with workers in other disciplines, especially crop protectionists, for any long-term trial of this nature to avoid ambiguous conclusions.

Acknowledgements

I am indebted to the soil chemistry staff for their untiring efforts in assembling the data. My thanks also go to Dr. J.F. Trieweiler of USAID, Serere, J. Oryokot, P. Esele and S.E. Odelle for helpful suggestions, and the staff of the Biometric Unit for analysis of the results. This paper has been prepared under the auspices of the UAFRO Administration.

REFERENCES

Adams, S.N. 1962. The response of sugar beet to fertilizer and the effect of farmyard manure. J. Agric. Sci. Camb. 58: 219-226.

Dennison, E.B. 1961. The value of farmyard manure in maintaining fertility in Northern Nigeria. Empire Journal of Experimental Agriculture 29: 330.

Djokoto, R.K. and Stephens, D. 1961a. Thirty long-term fer tilizer experiments under continuous cropping in Ghana I. Crop yields and response to fertilizers and manures. Empire Journal of Experimental Agriculture 29:191.

Djokoto, R.K. and Stephens, D. 1961b. Thirty long-term experi ments under continuous cropping in Ghana II. Soil studies in relation to the effects of fertilizers and manures on crop yields. Empire Journal of Experimental Agriculture 29:245.

Geus, de, J.G. 1973. Fertilizer Guide for the Tropics and Sub Tropics. Zurich: Centre d'Etude de l'Azote, second edition.

McWalter, A.R. 1972. Serere Research Station Annual Report, Part II, 1971/72.

Mouttapa, F. 1974. Soil aspects in the practice of shifting cul tivation in Africa and the need for a common approach to soil and land resources evaluation. In Shifting cultivation and Soil Conservation in Africa. F.A.O. Soil Bulletin No.24, Rome.

Norman, M.J.T. 1979. Farming Systems in the Tropics. University of Florida.

Nye, P.H. and Greenland, D.J. 1960. The soil under shifting cultivation. Harpenden, England: Commonwealth Bureau of Soils, Technical Communication No. 51.

Parsons, D.J. 1960. The systems of agriculture practised in Uganda. Memoirs of the Research Division, Department of Agriculture, Series 3, Nos. 1-5.

Snedecor, G.W. and Cochran, W.G. 1967. Statistical Methods: Ames Iowa: Iowa State University Press, sixth edition. 593 p.

ADOPTION OF SORGHUM AND FINGER-MILLET TECHNOLOGY IN UGANDA

Joseph O.E. Oryokot*

The two most important small-grain cereals grown in Uganda are finger millet and sorghum. Finger millet is the staple food crop in eastern and northern Uganda, and it is becoming increasingly important in western Uganda.

The need to raise the national sorghum and finger millet production to meet increasing food demands, led to the initiation in 1958 and 1965 of sorghum and finger-millet improvement programs at Serere. Since their inception these programs have been involved in technology generation, especially in the development of improved cultivars of the two crops. Agronomy research, to complement the varietal development work, was started in 1967.

The technologies generated have proven themselves in the research station and their potential for increasing the production of these crops cannot be disputed. Unfortunately, many of these new types have not reached the farmer and if they have, they have not been adopted to any significant degree. The technology and recommendations have included:

1. Varieties /hybrids

The sorghum and millet improvement program has released a number of sorghum and finger-millet varieties for the various ecological zones of the country. At the forefront of sorghum varieties are, Serena, Seredo and E 525 Ht. Reduction. These are brown-grained, short-statured and early-maturing varieties which have satisfactory levels of resistance to shootfly, Striga, and leaf diseases. Each variety is capable of yielding up to 5,000 kg/ha under good management. These varieties are recommended for medium potential areas at altitudes below 1,530 m. Other varieties released from the program include Lulu Tall, Lulu Dwarf, and Dobbs Bora. The hybrids developed at Serere include Hijack, Hibred and Himidi. These have outperformed other varieties in the more difficult environments.

Local varieties of finger millet have been improved, and these include Engeny, Gulu E and Serere I. P 224 has not been released officially, but yields of over 2,800 kg/ha have been consistently obtained.

---

*Agronomist, UAFRO, Sorghum and Millets Unit, Serere Research Station, P.O. Soroti, Uganda.

2. Management practices

(a) **Seed bed preparation:** Sorghum and finger millet are small-seeded grains. A fine and well prepared seed bed is important for establishment. Uneven stands result from cloddy seed beds. A well-prepared seed bed is also a prerequisite for row planting with seeders.

(b) **Time of planting:** Trials planted out in Kumi, Kitgum and Serere have shown that early planting in relation to the rains is essential for good yields in both sorghum and finger millet. Serena yields have been reduced from over 4,000 kg/ha to 1,100 kg/ha over a period of six weeks while the yield of Engeny has decreased from 3,100 kg/ha to 2,550 kg/ha in the same period. A total crop failure in late planted millet is possible in "bad" years. The recommendation for finger millet is to dry plant or plant just after the onset of the rains. Dressed sorghum seed can also be dry planted, although this should be as late as possible before the onset of the rains.

(c) **Spacing and plant population:** The optimum plant population for a given area depends upon the amount of available moisture, the nitrogen status of the soil and the size of the variety being grown (Doggett, 1970). The recommended spacing for the short improved varieties and hybrids is 60 cm x 15 cm. This gives a medium plant population of 111,000 plants per hectare. This population responds best to a wide range of moisture conditions. A wider spacing is recommended for the drier areas. In finger millet, a row spacing of 30 cm is recommended, the plants being thinned to 5 cm within the rows.

(d) **Fertitlity:** Generally, economic sorghum-yield responses may be obtained with 80 kg N and 40 kg P_2O_5/ha with N split applied at planting and 20-30 days after germination. Farm yard-manure applied at 100 q/ha often gave sorghum yields double that of the untreated plots.

In finger millet, the addition of N without P_2O_5 did not significantly increase yields. An economic crop yield of 22.6 q/ha occurred with 100 N and 110 P_2O_5 kg/ha. Fertilization with manure or inorganic fertilizers is a must for good finger-millet yields, especially in over-cultivated soils.

(e) **Weed control:** Good weed control should start with seed-bed preparation. A good seed bed ensures good germination and vigorous crop growth. Though sorghum can compete well with weeds, once established, it is necessary to keep fields clean in the early stages. Finger millet should be kept weed-free for the first six weeks after emergence. For both cereals, two weedings at two and six weeks after germination have been found to give good yields. Delayed weed control tends to increase labor requirements, especially with finger millet.

Where Striga is prevalent, physical removal before flowering is advised to keep the population in check. A rotation with groundnuts and cotton is recommended. In this country, no chemical is presently recommended for weed control on these cereals.

(f) **Pest and disease control:** Sorghum shootfly and stalk-borers are the most important pests of sorghum. Chemical control is both expensive and dangerous to farmers. Application of fertilizers is recommended as this may help the crop to grow away from the shootfly-susceptible stage and recover more quickly. Reduction of volunteer plants and crop residues after harvest reduces carry-over, especially of stalk-borers. The growing of improved varieties/hybrids which show resistance to pests and diseases is presently recommended.

Adoption of technology and production compromises

In spite of the nearly 30 years of improvement work in sorghum and finger millet, national production of these crops has not significantly improved, although the total area has increased. Local varieties continue to dominate. Seed broadcasting, late and/or staggered planting, interplanting, scant or late weeding and absence of fertilizer application, continue to be the main features of the husbandry of these crops (Table 1). A number of factors which characterize the farming system seem to perpetuate this state of affairs. These can be put into three: technical, economic and social.

1. **Technical**

(a) **Inadequate extension services:** The dissemination of information on new food-crop varieties is poor. In surveys carried out in 1975, 1981, and 1985 not many of the farmers interviewed had heard of improved sorghum varieties and even less actually grew them. All farmers had heard of row planting of sorghum and finger millet but all those interviewed planted only cash crops in rows.

Table 1. Results of a survey on millet production in Soroti District.

Sample technology recommendation	Used/ practised	Not used / Aware	Practised Not aware
Plough	22	8	0
Weeder	0	30	0
Seeder	0	30	0
Ox-cart	7	23	0
Early planting	11	15	4
Pure stands	2	28	0
Two weedings	6	24	0
Fertilizer application	0	30	0
Manure application	1	29	0
Row planting	0	30	0
Improved varieties	0	12	18
Storage insecticides	0	0	30

Source: Amulen, 1981

In 1985 farmers'recollections about their sources of agricultural information were varied. Many could not remember when they were last visited by the extension agents or heard any information on farming. A few mentioned mass meetings at administrative centres as their main sources of agricultural information.

(b) **Unavailability of improved seed:** The lack of a mechanism for seed distribution is a glaring bottleneck in the adoption of improved varieties and hybrids. In the absence of any facilities for getting improved seed to the farmer, the plant breeder works largely for his own satisfaction and is unable to see his work make any impact on local farming. The Uganda Seed Multiplication Scheme has remained a caricature of what was envisaged. This was made worse by the war of liberation, from which the Scheme has never recovered. The amount of seed that the program at Serere tries to distribute is grossly inadequate. Recently, charity and church organizations have helped in supplying sorghum seed to farmers in Karamoja. Sometimes this seed is neither pure nor improved. In a recent survey all those farmers who grew Serena seed either bought it from their primary co-operative societies or obtained it from a neighbour or relative.

(c) **Susceptibility to bird damage:** Birds seem to be the biggest obstacle to the ready adoption of improved sorghum varieties. In the survey conducted this year, all farmers who had heard of and/or grew improved sorghum, mentioned bird damage as the reason for the limited cultivation of these varieties. Because of the small fields and the isolated farms which grew these varieties, bird damage was greatly magnified. The labor for bird scaring is simply not available.

(d) **Susceptibility to storage pests:** The farmers interviewed classified the storage ability of Serena as poor. The improved varieties are readily attacked by the rice weevil, flour beetle, and the grain moth in the traditional storage structures or in sacks.

(e) **High inputs and management:** Many of the sorghum varieties have been developed for a higher level of management than the farmers for whom they are intended can manage. All farmers interviewed broadcast their sorghum and finger-millet seed. This was in spite of a campaign and a subsidy scheme, launched by Government as early as the 1960s, to popularize the seeder. In a recent survey it was found that no farmer owned an operational seeder in the whole of Soroti and Kumi Districts.

Farmers continued to make more than one planting of their sorghum and millet crop in any one season, i.e. staggered planting. The main reason given was to spread the labor requirement, especially for weeding and harvesting. Risk management, particularly due to the vagaries of the weather, was advanced and a reason by a few of the farmers. Linked with risk management was the prevalence of interplanting of millet and sorghum in various ratios.

All farmers interviewed weeded their sorghum and finger-millet crops once, but a secondary weeding could be required in finger millet. This was commonly the case in over-cultivated fields or when too much rain followed the main weeding.

None of the farmers interviewed applied fertilizers to their sorghum and millet crops. In Kumi and Ngora counties, areas of extreme pressure on land and soil exhaustion, application of cattle manure, notably to finger millet fields, was common. The reasons given for non-application of fertilizer were: cost, unavailability, and lack of technical information. None of the farmers practised any crop-protection measures due to lack of knowledge or information about any such measures.

An illustrative example of the existing level of technology adoption is seen in what has come to be called the "Peoples' Farm" at Serere Research Station. A few blocks of land were given to the staff for their own use. Sorghum and finger millet were the main crops grown. The staff are mainly agriculturally trained personnel with professional training, ranging from Agricultural Assistants with certificates in agriculture to graduates. A simple survey of these "farmers" did not reveal any difference in adoption of technology from the farmers in Kumi and Soroti Districts as far as sorghum and finger millet production were concerned. None grew an improved sorghum variety in the first rains of 1985. However, P 224, a yet-to-be-released variety was the most common variety grown. None planted their sorghum and finger millet in rows, weeded millet twice, applied fertilizer or practised any crop protection. This was not the case with groundnut cultivation, for example, in which all recommendations were faithfully followed.

Besides unavailability of inputs and cash, labor seems to be the biggest constraint. Considering the time required to row plant, thin, weed twice, apply fertilizer if it were available, spray and harvest, one must not only consider whether the recommendation will succeed but also whether the farmer will be physically able to give the extra time required if he adopts the technology/recommendation. A farmer without recourse to hired labor would have to reduce the area of crop, and, therefore require a much higher guaranteed response. Thus, in adopting a particular recommendation, a farmer whose labor supply is limited is taking a risk which may even result in reduced gross yield (Baker, 1967). Even farmers who are able to hire labor would need to decide to which of their crops the additional labor should be applied.

2. Economic

(a) **Limited use:** These two cereals are nearly always used for food and brewing. There are possibilities of their expanded use in poultry and livestock feed formulation. Presently their uses are limited and no economic investments seem to warrant their large-scale production for the market. Farmers only have to meet their own yearly food requirements. Beyond this, there is little incentive for increased production.

(b) **Underdeveloped marketing structure:** Agricultural development is bound up with changes in agricultural technology and accumulation of capital through an efficient marketing system (Oloya and Poleman,1968). Past attempts to increase food production have not been successful, largely because of difficulties in the marketing sector. By contrast, those crops with external markets, mainly the cash crops, have witnessed considerable development. Sorghum and finger millet are non-statutory controlled crops and their prices and demand are dictated by the cropping seasons. The only marketing avenues open are the weekly local markets or shops. Improving the marketing structure is essential if farmers have greater incentives to adopt new technologies. All available innovations for increasing crop output involve added costs. Farmers will accept these costs only if some of the crop can be sold to pay for them and at high enough prices to make the innovations attractive. The use of sorghum in the production of lager beer should change the picture drastically. The knowledge of this potential in Serena sorghum resulted in an unprecedented rush for seed last year.

3. **Social**

The farmers themselves advance number of reasons for not adopting the improved materials. A few improved finger-millet materials are alleged not to brew well. This, if true, is of importance considering that the two main roles of millet are for food and brewing. Certain sorghum varieties, such as 2KX 17/B/1, are said not to be as tasty as the local varieties. No figures are yet available.

Conclusion

Much of the sorghum and finger-millet technology has been rejected wholly or adopted with modifications. When they were developed, many of these technologies considered only the technical factors in increasing yields, and few or none of the economic and social factors prevalent in farming systems. For the generation of readily acceptable or adoptable technology, knowledge of the local farming systems is very important. The farmer's readiness to adopt a technology is closely related to the degree to which such technology will cause the farmer to change his farming system as influenced by technical, economic and social factors. A technology that has the best chance of success is that which will require the least change in the farming system.

REFERENCES

Amulen, F. 1981. Survey on millet production in Soroti District with particular reference to Serere County. Special Project for Award of B.Sc. (Agric.) Makerere University.

Baker, E.F.I. 1976. Effects and interactions of "package deal" inputs on yield and labor demand of maize. Ahmadu Bello University, Institute for Agricultural Research, Samaru Research Bulletin 254.

Doggett, H. 1970. Sorghum. London: Longmans, Tropical Agriculture Series.

Oloya, J.J. and Poleman, T.T. 1968. The food supply of Kampala: A study in the marketing of bacic food-stuffs in an African metropolitan area. Kampala: Makerere Institute of Social Research.

THE ROLE AND STATUS OF SORGHUM AND FINGER MILLET IN THE TESO FARMING SYSTEM

J.O.E. Oryokot and B.A. Opolot*

The Teso farming system is one of the seven major farming systems in the country. It is largely limited to Soroti District in the north and north-west, Kumi District, and a large part of Pallisa Sub-District of Tororo District to the south and south-east. The system is characterized by the universal opening of land by ox-ploughs although this technology has not been adopted further than primary tillage. It is based on the production of annual crops, including finger millet and sorghum, in an environment of light and infertile soils, heavy precipitation in the two rainy seasons and a prolonged dry spell from December to March (Jameson, 1970). Population density follows a marked south/north gradient, declining to its lowest in the extreme north of Soroti District. The rainfall pattern can be said to follow the same gradient, declining northwards. Cattle are an integral part of the system.

Land in the farming system is largely held under customary inheritance, although sale of land is common in Serere. The average size of holding ranges from slightly over five hectares in Soroti District to under one hectare in much of Kumi District. Renting of additional land is common in Kumi. The farming system is characterized by a lack of off-farm jobs. Those off-farm jobs often mentioned are fishing in lake-side areas, brewing, and petty trading.

The main food crops are sorghum, cassava and finger millet, in that order. Other food crops include sweet potatoes, cowpeas, groundnuts and simsim. Up to the mid-1970s cotton was the main cash crop but, the situation seems to have changed dramatically since then with finger millet, cassava and groundnuts being named as the main sources of cash.

This farming system incorporates more definite crop rotations than most others. The most commonly described rotation has cotton in the first year of opening, followed by finger millet and cowpeas in the second rains of the second year's cultivation. In the third year any other crop may be incorporated in the system, followed by a fallow period. The use of finger millet as the first crop in the rotation, in new or rested land, has become prominent. This is especially so in Kumi District, giving the district a distinct farming system where cassava is used for "resting" the land.

Role of sorghum and finger millet

For many years sorghum has been regarded as an insurance against a possible dry season. Sorghum was only eaten when the more favoured millet supplies ran out, otherwise it was mainly brewed. The events of the last few years have changed this situation. Sorghum is now named by farmers as the main staple food eaten all the year round. Although no precise production figures are available for the system as a whole, sorghum can now be regarded as the leading food cereal. Farmers do not distinguish between the roles of red and white sorghum. They are all used for food, the only difference being in the sorghum/cassava ratio used when they are mixed, the proportion of the sorghum being higher. The sorghum is eaten as atap (a stiff porridge) or ugali. Sorghum may also be brewed pure or mixed with millet. The crop is gaining in importance as a source of cash for the family.

Millet was the leading food staple in the system until a few years ago. As was seen above, this role has been increasingly assumed by sorghum, while finger millet is now a major source of cash. Nowadays finger millet is only eaten immediately after harvest, from July to August, changing roles thereafter. According to a recent survey, finger millet now ranks second after cassava as a source of cash. The importance of this crop in the Teso domestic economy is shown by the large hectarage devoted to it. In most farms, irrespective of economic class, it occupies more land than all other crops in the first rains. The sale of this crop has achieved a high level of standardization throughout the farming system. Finger millet may be sold directly for cash at local markets or brewed and the beer sold for cash. Due to the marked absence of storage pests, finger millet may be stored until market conditions are right for its disposal. Finger millet may be used in the payment of labor, either as beer or directly.

Status of the crops

Ideally sorghum is a second-rains crop followed either by groundnuts or millet in the rotation. Due to the increasing frequency of "bad weather" years sorghum has become more popular with Teso farmers.

In the first rains, the area under sorghum is less than that under millet, and it is commonly interplanted with finger millet. It may also be planted after a failed millet crop. In the second rains, sorghum is planted in August/September in pure stand or interplanted with pigeon peas or even cassava. Although a number of improved sorghum varieties have been developed, none of these is widely grown by farmers.

Millet has always been the leading cereal in the system. There was a very strong positive correlation between cotton and millet acreages in the mid-1970s (Uchendu and Anthony, 1975). Though the area under cotton has declined, the millet area has remained fairly constant. A few farmers, however, are of the opinion that the cotton decline has had a negative effect on finger-millet production. This is mainly because the fine seed-bed that was realized from cotton fields made dry-planting of millet easier.

No improved varieties are grown, and the leading local varieties are, Emiroit, Emoru, Engeny and Ebeggar (Amulen, 1981). These varieties may all be found mixed in one field. Traditional methods of production continue to be followed. The time for planting ranges from February, when it is dry-sown, to May. Millet is uncommon in the second rains.

Constraints in sorghum and millet production

A number of constraints seem to predominate at the farm level. Birds seem to dictate the status of sorghum. Many of the white-seeded and improved sorghum varieties are heavily attacked. This seems to be the main obstacle to the adoption of improved varieties and the reason for the insignificant hectarage in the first rains.

Sorghum is particularly prone to pest damage both in the field and in storage. Storage pests are a definite problem in the improved varieties. Traditional storage structures provide little protection against these pests. Striga has become important, particularly in the Ngora and Kumi Counties of Kumi District.

Finger-millet production is constrained by labor for weeding and harvesting. It is a very labor intensive-crop. In this year's survey, the largest labor requirement was at weeding and harvesting. The labor at a farmer's disposal seemed to determine the size of the area under finger millet. The existence of labor bottlenecks in the system makes the preparation of seed-beds difficult, worsening the amount of weeding required. The traditional method of broadcasting millet compounds this situation. Due to the small size of millet seedlings, weeding is started late and extends longer, leading to considerable losses.

Finger millet is sensitive to fertility levels. In the Teso farming system, no fertilizer is applied on finger millet. This has resulted in the decline of yield in many areas, especially those areas which, due to population pressure, practise continuous cropping.

REFERENCES

Amulen, F. 1981. A survey on millet production in Soroti District with particular reference to Serere County. Special Project for Award of B.Sc. (Agric.) Makerere University.

Jameson, J.D. 1970. Agriculture in Uganda. Oxford University Press.

Uchendu, V.C. and R.M. Anthony. 1975. Agricultural Change in Teso District, Uganda. Nairobi: East African Literature Bureau, 1975.

THE ROLE OF OX-CULTIVATION IN SORGHUM AND MILLET PRODUCTION IN UGANDA

Alphonse E. Akou*

The employment of oxen by farmers with limited technical know-how and resources for expensive farm equipment will continue in Uganda for many years to come. This is particularly so in areas where ecological conditions permit the keeping of cattle and farmers of the area have an interest in crop production. Where ox-cultivation has been established for many years, farmers have learned through experience the advantages of ox-drawn cultivation implements over the use of hand tools. What remains to be accomplished is the training of the farmers in the management and handling of oxen, and care and use of the ox-drawn implements.

Historical background

The use of oxen as source of power in Uganda dates as far back as 1909 when they were first introduced in Bukedi District of eastern Uganda and a year later in the neighbouring Teso District.

In introducing ox-power the European colonialists aimed to boost production of cotton as a foreign-exchange earner. This was mainly in short grass or finger-millet areas such as Teso where long term use of oxen is evidenced by large areas bare of trees which were destroyed to allow ox-ploughing and strip cropping along the contour, a policy advocated by the Department of Agriculture to control soil erosion.

The technology was also considered appropriate because it would:

- Provide better crop husbandry practices;
- Reduce the amount of slow and tedious hand hoeing required;
- Allow timely planting of crops thus spreading the labor peak;
- Encourage integration of livestock and crop farming.

The first ox-drawn implements used were the **Victory**/Ransomes, relatively heavy single-furrow steel mould**board** ploughs from Britain. Up to six small East African Zebu **oxen** were required to provide the power for ploughing. The lighter Safim ox-ploughs from South Africa came onto the market after the Second World War. Two or four oxen can be used on sandy soils.

---

*Head, Ox-cultivation Unit, Department of Agriculture, Serere Research Station, P.O. Soroti, Uganda.

At the beginning, ox-cultivation met with considerable difficulties because many people had prejudices against working oxen and they did not know what to do with them at the end of their working lives. To slaughter or sell an ox after it had rendered valuable service was considered inhumane. Others refused to adopt the technology on the grounds that the ox-plough ruined their land. However, after a hard struggle the Department of Agriculture managed to break through the resistance and oxen for draught were adopted in most parts of eastern and northern Uganda and in some parts of Bunyoro District in western Uganda. The spread of ox-cultivation technology has been sporadic. Some areas are too steep for ox-cultivation, e.g. Bugisu in eastern Uganda and Kigezi in western Uganda. The pastoralists found in parts of eastern and western Uganda take no interest whatsoever in crop production.

The potential of ox-cultivation

For many years the Department of Agriculture encouraged smallholder farmers to adopt ox-cultivation technology for the following farm operations in order to increase their crop production:-

Primary tillage: Opening-up of the land with the ox-plough and leaving it fallow for a period of six weeks to allow the vegetation to rot before a second ploughing.

Secondary tillage: Cultivators, discs, or harrows are used for seed-bed preparation.

Planting: Oxen are used for planting crops in rows with seeders attached to tool-bars or behind the conventional ox-plough. Row planting is a prerequisite for inter-row cultivation with ox-drawn cultivators.

Transport: Where a farmer deems it necessary to apply farm-yard manure on his field, ox-carts can be used for transporting the manure to the fields. The ox-cart can also be used for transporting farm produce.

However, these practices have not been fully implemented due to:

- An inadequate supply and high cost of appropriate ox-drawn implements/equipment;

- Farmers'reluctance to accept the new idea of ox-power;

- The small number of ox-cultivation field staff to spread the technology more widely.

Current practice

Farmers clean and burn bush during the dry season (December-January) to allow the earliest rains to encourage weed growth. When the soil is made soft enough by rain received in March/April, fields are ploughed with oxen and finger millet sown alone broadcast by hand or occasionally mixed with sorghum. Covering of the seed is done by oxen or the use of branches. In the case of sorghum alone, the seed is sown on a hand-cultivated field and ploughed in with the ox-plough adjusted for shallow ploughing. This is a very common practice in Karamoja.

For many years oxen have been used for the first and second ploughing, and to some extent, for transport, mainly of wood. In the case of transportation of crops, harvests are packed in gunny bags in the field and loaded on ox-carts which are pulled by a pair of oxen. Farmers who do not have ox-carts use forked branches for transporting farm produce from the field to the homestead. Otherwise, traditionally, farm produce is transported by women on their heads.

The extent to which oxen are currently used in Uganda is indicated in Table 1.

Table 1. Percentage of total arable land cultivated using oxen (estimated)

District	% of total arable land cultivated using oxen
Kumi	90
Soroti	90
Bukedi	90
Kitgum	80
Lira	60
Moroto	50
Apac	30
Gulu	30
Kotido	25

A rough estimate of the number of ox-ploughs in each district ranges from 5,000 in Gulu to 100,000 in Soroti District, with only half of these being operational in most districts.

The Government started tractor-hire services in the 1940s in an attempt to make subsistance small-scale agriculture more economic. The idea was accepted in many districts, but in Teso farmers had learned the advantages of ox-ploughing through experience and preferred it to the tractor.

Recent ox-cultivation research and development

Intensive research into ox-drawn implements/equipment and ox-training methods were carried out at Serere Research Station from 1960. This effort was directed towards planting, weeding, and transportation of farm produce and water.

In order to carry out these farm operations efficiently, the oxen and the people had to be properly trained. The-one man, or Indian, method of handling oxen was introduced by an Indian and was tried at Serere Research Station with success. It consists of one man controlling a pair of oxen with a rope or reins attached to the nose rope and one person controlling the implement. It takes up to six weeks to train a pair of oxen for this system.

A versatile range of ox-drawn implements/equipment was received from different countries for testing and when necessary modified to suit local conditions. These were: the NIAE tool bar from Britain, the Planet Junior cultivator from U.S.A., the Polycoulteur tool-bar and ARIANA tool-frame from France. Bentall Seeders were also introduced and A.H. Seeders were developed in Uganda. Both seeders were first fitted to the hand-pushed frames (Serere Push Frame) and tried for planting crops with varying seed sizes. The Bentall was found best suited for planting finger millet. It was observed that with its use there was no need to cover the seed. However, of all tool-bars tested, the Polycoulteur was found superior to any other ox-drawn tool-bar for seed-bed preparation, especially for finger-millet dry planting. The main advantage of dry planting this crop is that it makes maximum use of any rain received early in the season, thus enabling the farmer to devote more time to preparing seed-beds for other crops.

Two or three Bentall A.H. Seeders are attached to the Polycoulteur tool-bar and spaced at 30 cm for planting finger millet or 60 cm for sorghum and other crops. About half a hectare can be planted in an hour. To achieve proper spacing between crop rows it is important to use an appropriate yoke length. A simple guide for planting or weeding is to use a yoke whose length is double the crop-row spacing, e.g. the yoke length for crops whose spacing is 60 cm would be 120 cm.

At Serere, after intensive research and development of ox-drawn implements, sowing and weeding crops in rows with oxen has been successfully carried out. Well trained oxen walk straight between crop rows without damaging crops. Another important achievement in the investigation on animal draught, is farm transport. Locally made steel ox carts are in use. Spraying equipment is also operated with ox-power.

Whenever possible the ox-cultivation staff carry out effective demonstrations of all improved farm practices with the use of animal draught. In the 1960s, when facilities to do this more effectively existed, many farmers accepted the idea. With the death of group farms, a continuing lack of supplies for ox-drawn implements and spare parts, and little backing of the technology by the policy makers of the Department of Agriculture, the improved methods/skills disappeared from the farming community and remained "dormant" on Government farms.

Conclusion

It is difficult to assess the impact which the development and spread of ox-cultivation has had on the production of sorghum and millet in Uganda, particularly when its use is limited to a few districts and only for the first and second ploughings, leaving the remaining farm operations to women.

SORGHUM AND MILLETS - THE KARAMOJA EXPERIENCE

J.R. Rowland*

Karamoja, comprising Kotido and Moroto Districts of Uganda, borders Sudan to the north and Kenya to the east. Essentially a gently rolling plateau 1,100-1,400 m in altitude, the land is more broken and mountainous in the north. Elsewhere, occasional isolated mountains and hills break the monotony of the landscape.

The climate of the region is not uniform. It varies from semi-arid in the east-central parts, to sub-humid in the extreme south-west and north. Mean annual rainfall varies from about 500 mm to over 900 mm, but variation between years at a given site may be up to 50% of its mean. Moreover, though the "normal" rainy season is nearly monomodal (from March or April to September with a dry spell in June or July), in practice distribution can be highly erratic. Combined with fairly high temperatures (typically 18-20° min. and 28-30°C max.) during the rains and dessicating winds during dry spells, this results in a high drought risk which manifests itself in about four serious crop failures in ten years.

Karamojong-speaking peoples predominate in the region. These are traditionally pastoralist though the amount of agriculture they practise has become increasingly important this century. Indeed, the depredations of cattle raiding, livestock disease and famine have reduced livestock numbers to the point where it is plain that most of the diet must come from agricultural products. In the drier inhabited regions their agriculture is based on sorghum, with variable amounts of maize, cucurbits, and minor crops such as beans, grams, groundnuts, tepary beans, cassava, sweet potatoes, finger millet, and cowpeas. In the north, pearl millet is an alternative staple. Sunflower is a new crop, spreading quite rapidly, for local consumption and small-scale processing. Though there are no reliable statistics, we estimate that sorghum constitutes about 70% of the cultivated acreage, except where pearl millet is extensively grown.

In the wetter and more fertile fringes, the population is either non-Karamojong or the Karamojong are settlers. Here maize and finger millet compete more successfully with sorghum.

---

*Manager, Karamoja Seeds Scheme, P.O. Kotido, Uganda.

Broadly speaking, in the higher rainfall areas, the colluvial soils are very fertile and black-cotton soils moderately so. In the drier central plains, black-cotton soils predominate over large areas, with substantial areas of light sandy loams. Except where over-cultivation and erosion have occurred, these are capable of supporting good yields.

The present state of sorghum and millet production

Sorghum is the staple of most Karamojong and it is consumed as atap (stiff dough), porridge, nikawo (whole boiled grains), or beer. The atap is eaten with relishes (pulses, groundnuts, simsim, cucurbit seeds) milk or ghee, when these are available. Consequently, when harvests are good, the diet is adequate, though crop failure frequently results in starvation and death.

Sorghum is well adapted ecologically over the whole region, and usually outyields other cereals. However, cereal-crop diversification is highly desirable in order to spread the possible planting period and seasonal work load. Finger millet, early maturing maize, and pearl millet can all be planted later than sorghum without excessive risk of pest damage. Late planted sorghum is susceptible to attack by stem borers, midge and shootfly. The millets have the advantages of greater palatability and longer storage without pest damage.

a) **Sorghum**

The two predominant local types are Karamojong and Kabir, which take 4 to 6 months to mature. Traditional sorghum production suffers from labor constraints. Hand-hoe cultivation cannot, in the drier areas at least, achieve food self-sufficiency, as yield per hectare is so low. Black-cotton soils may be prepared during the late dry season and dry-planted. Sandy soils usually need softening with rain before cultivation is possible. Dry-planting is risky because early rain may not be sustained. On the other hand, digging when the soil is wet tends to result in much late planting. In either case, seed is broadcast before cultivation. Row planting has not yet been adopted on any scale. Ox-ploughing is practised by many families, and on an increasing scale, and does give the possibility of cultivating sufficient land to provide enough food for the family in most years. Statistics are scarce, but with a hand-hoeing regime, yields of about 500 kg/ha have been reported in "average years" on the dry plains, but 1,500-2,000 kg/ha in the fertile fringes. Without ox-cultivation one hectare per family seems about the maximum. Plainly, this is not enough to feed two adults and their children for a whole year. This must be supplemented by livestock products, purchased foods, and wild products, or starvation results. It is therefore extremely urgent to find ways of consistently improving sorghum and other crop yields in Karamoja.

b) **Finger millet**

Several local finger-millet varieties or mixtures have been borrowed from the western neighbours of the Karamojong (Labwor, Teso, Acholi, Langi). Cultivation is on a very small scale. Millet is frequently intercropped with sorghum or other crops.

c) **Pearl millet**

This crop is mainly confined to the north of Kotido District, i.e. Dodoth County and north Jie. In Dodoth, pearl millet is grown on colluvial soils where mean annual rainfall exceeds 1,000 mm, as well as on drier sites with poorer soils. The traditional variety is non-bristled and grows to a height of about 2 metres under good conditions. Pearl-millet cultivation is similar to that of sorghum but usually it is planted later. In fact, it can be planted into July even in drier areas, thus giving a chance of a reasonable harvest even when young sorghum is destroyed by drought or armyworm. This advantage makes it desirable to spread the crop throughout Karamoja, but an assumed susceptibility to birds has prevented this in the past.

Sorghum and millet research in Karamoja since 1972

Karamoja lies in that part of Uganda served by Serere Research Station. Unfortunately, there has never been a sub-station in this region, which is far drier and less developed than most of the country. Four district variety trial centers (DVTC) were established (Namalu, Iriri, Moroto, Kotido) but two are on the fringes of higher-rainfall areas, one is a non-representative site at the foot of Moroto Mountain, and only Kotido is typical of the dry plains. In recent years, problems of supervision have led to disappointing results from the DVTCs.

The Church of Uganda established a small project called the Karamoja Agricultural Project in 1972 at Kaicheri, 20 miles north-west of Kotido. Realizing how little research experience there was available for Karamoja, the management of the project decided to begin with variety trials and crop introduction and testing. More than 30 crop species were tested and in several cases large variety collections were grown. Some material was tested at a second dry site (Nabuin District Farm Institute). Owing to limited resources, little agronomic work was done. This research phase continued until 1976, after which the project became semi-moribund, owing to political and economic difficulties, until 1979. From that year, the priority was seed production and the KAP became the Karamoja Seed Scheme (KSS). It was essential to have this facility for producing dryland-crop seed of which, often, is not available in East Africa. Despite the droughts and other difficulties of the next few years, KSS managed to build up a system of outgrowers to produce seed of acceptable quality for supplying farmers and development agencies. At the same time, further sorghum-variety testing and selection from earlier crosses continued until several KAP experimental varieties were produced and evaluated.

From 1976 it was decided to release the following:

Sorghum
The variety Seredo (5DX 135/1/3/1/) had done well in KAP and Serere trials both in Karamoja and elsewhere in Uganda. More recently it has emerged as an outstanding widely adapted sorghum that has been successful in Uganda, southern Sudan, Kenya, Tanzania and other countries.

Pearl millet
Serere Composite 2 was promising in Karamoja and officially released in Uganda. Also, like Seredo, it has done very well in many eastern African countries. In fact, it has now been officially released in Sudan under the name "Ugandi".

Finger millet
Under marginal conditions in Karamoja, no improved variety was impressive. A local type was taken for multiplication but it was eventually lost by mismanagement. Much more recently, the Serere variety, which is on restricted release in this country, is being provisionally bulked.

KSS now has the capacity to produce sorghum seed in excess of Karamoja's needs, except in very dry years, and now has the approval of the Uganda Seed Project to produce Seredo for other areas of the country. An export potential also exists.

Sorghum research

The following are identified as areas of critical concern in the daunting task of increasing sorghum production in Karamoja. Many of the problems apply also to the millets:

Varieties

Seredo has shown a total yield advantage of 24% over the standard local variety in 20 yield trials since 1973. All variety trials were conducted without fertilizer pesticides, though, for convenience, most trial sites were ploughed by tractor. Several were ox-ploughed or hand dug. Apart from KAP trials, we have been planting ICRISAT and more recently, Serere and East African Co-operative Trials. At various times, west African, southern African, Kenyan, Ethiopian and Sudanese varieties have been imported. No exotic has proved immediately useful, but several ICRISAT varieties, among others, did get promoted to KAP trials. All of these had good quality grains, but farmers in Karamoja are wary of white varieties because of birds.

Interestingly, Seredo's yield was more stable than that of the local variety and in poor environments its yield advantage was greater, in contrast to the case of many improved crop varieties. This stability seems to be a product of a relatively short maturity period and tolerance to drought and pests.

Table 1 groups the trial results into high- and low-yielding categories. Mean yield of all varieties for each trial is used as a measure of environment, whether the year-site combination was "good" or "bad" for sorghum. This is a very crude index, especially as rainfall, time of planting, soil fertility, effects of pests and diseases, and management, all combine to affect "environment", and the varieties included are not exactly the same in every trial. However, clear differences emerge between Group A (9 trials with mean yields over 1,000 kg/ha) and Group B (11 trials with mean yield less than 1,000 kg/ha). In group A the mean of the yield advantages to Seredo at each site was 53% but in Group B, representing poor growing conditions, it was 118.7%. Looking more closely at these results, we may get a good comparison of yield stability by examining standard errors of means and co-efficients of variation for each variety across all trials in which they appear. The lower the values of these two factors, the greater the yield stability. A more refined statistical approach to estimating the stability of variety is that proposed by Eberhart and Russell (1966)*. The mean yield of the whole trial is used as an estimate of environment and the regression of each variety on this figure is calculated. From this, the co-efficient of correlation (r) is used to estimate stability, and low values for the slope of the regression line and r indicate good stability over the sites and seasons.

---

*Eberhart, S.A. and Russell, W.A. 1966. Stability parameters of comparing crop varieties. Crop Sci.6:36-40.

Table 1. Comparison of trial mean, Seredo, and local variety yield for 20 trials grown in Karamoja, 1973-1984

Table 1. Comparison of trial mean, Seredo, and local variety yield for 20 trials grown in Karamoja, 1973-1984.

Group A: High yields

Trial	Trial mean yield (kg/ha)	Seredo Yield (kg/ha)	Local yield (kg/ha)	Seredo yield advantage	C.V., %
1. Kotido major 1982	1887	2456	2439	+ 0.7	22.9
2. Kaicheri major 1983	1885	2601	2107	+23.4	24.4
3. Moroto major 1983	1700	2358	2405	- 2.0	19.6
4. Kaabong'minor 1982	1602	2917	2560	+13.9	32.9
5. Kaicheri major 1982	1412	1652	1875	-13.5	25.1
6. Kaicheri main 1981	1315	1219	254	+380.0	52.6
7. Nabuin 1973	1277	1065	806	+32.1	25.1
8. Kaicheri minor 1983	1253	1938	1512	+28.2	34.6
9. Kaabong'exotics 1981	1245	1429	1255	+13.9	-
Mean	1508	1959	1690	53.0	33.7
Group B: Low yields					
10. Kaabong' major 1983	800	1546	1788	-15.7	30.9.
11. Namalu major 1983	737	1358	350	+288.0	29.3
12. Matany major 1983	694	969	1038	- 7.1	36.9
13. Kaabong' main 1981	654	1332	739	+80.2	40.8
14. Kotido major 1983	627	930	732	+27.0	32.7
15. Nakapiripirit major 1983	448	740	514	+44.0	62.7
16. Kotido minor 1983	399	852	694	+22.8	41.6
17. Iriri main 1981	387	789	232	+240.0	46.9
18. Kapedo major 1982	361	564	439	+28.5	39.9
19. Kaicheri KAP 1984	318	286	256	+11.7	55.7
20. Matany main 1981	165	350	51	+586.0	-
Mean	508	883	621	118.7	41.7

In considering the benefits of substituting Seredo for the farmer's local variety, one must bear in mind what happens in the poorer years, since food security is the farmer's first priority. Group B shows that the greatest advantages are in such a year. For example, in the Matany main trial 1981, when the rains finished at around the Seredo flowering time, the local variety effectively failed, but Seredo gave a useful yield. Conversely, local sorghum is at its best when rains are more extended or when drought is severe around the floral initiation stage of Seredo, at which time the local variety is still resistant to drought.

Although the comparisons Seredo vs local, Seredo vs mean yield of trial, and local vs mean yield of trial give quite a good fit to a linear regression of the formula $Y = a_o + a_1X$ (Fig.1) an interesting effect can be seen by plotting Seredo/local against local (Fig.2). The distribution of points obtained suggests as curve of the following type:-

$$\frac{\text{Seredo}}{\text{local}} = \text{a.e.}^{-\text{ b local } + 1}$$

This graph shows quite dramatically the increasing advantage of growing Seredo as "environment" becomes more severe.

An examination of the co-efficients of variation for all the trials in Table 1 shows a substantially higher mean C.V. for Group B. Under drought conditions it is observable that plants growing on areas of hard or raised soil within the trials show water stress long before those growing on soft or lower areas. The implication is that dryland research needs very uniform and level sites, or else high C.V.s are likely.

Seredo is, at least initially, less acceptable as regards storage and flavour in Karamoja, though farmers appear to get used to it and even prefer it later.

Palatability testing has been hampered by both crude techniques and lack of computational facilities for analysing results. Assessing five or six varieties at once has proved too difficult for the 40-70 randomly-chosen Karamojong who took part in the tests. Only very noticeably different samples are clearly identified.

The disadvantages of Seredo were recognized since the first research period (1972-1976). At that time, good grain quality sorghums adapted to Karamoja were hard to come by. In 1975, the project made a cross between Seredo and a good-grain, corneous variety obtained from an exotic nursery. From this, a very varied set of KAP varieties was obtained and later tested alongside standard and other improved varieties. As yet, no very definite successor to Seredo has emerged, though some new Serere varieties and some KAP varieties show promise.

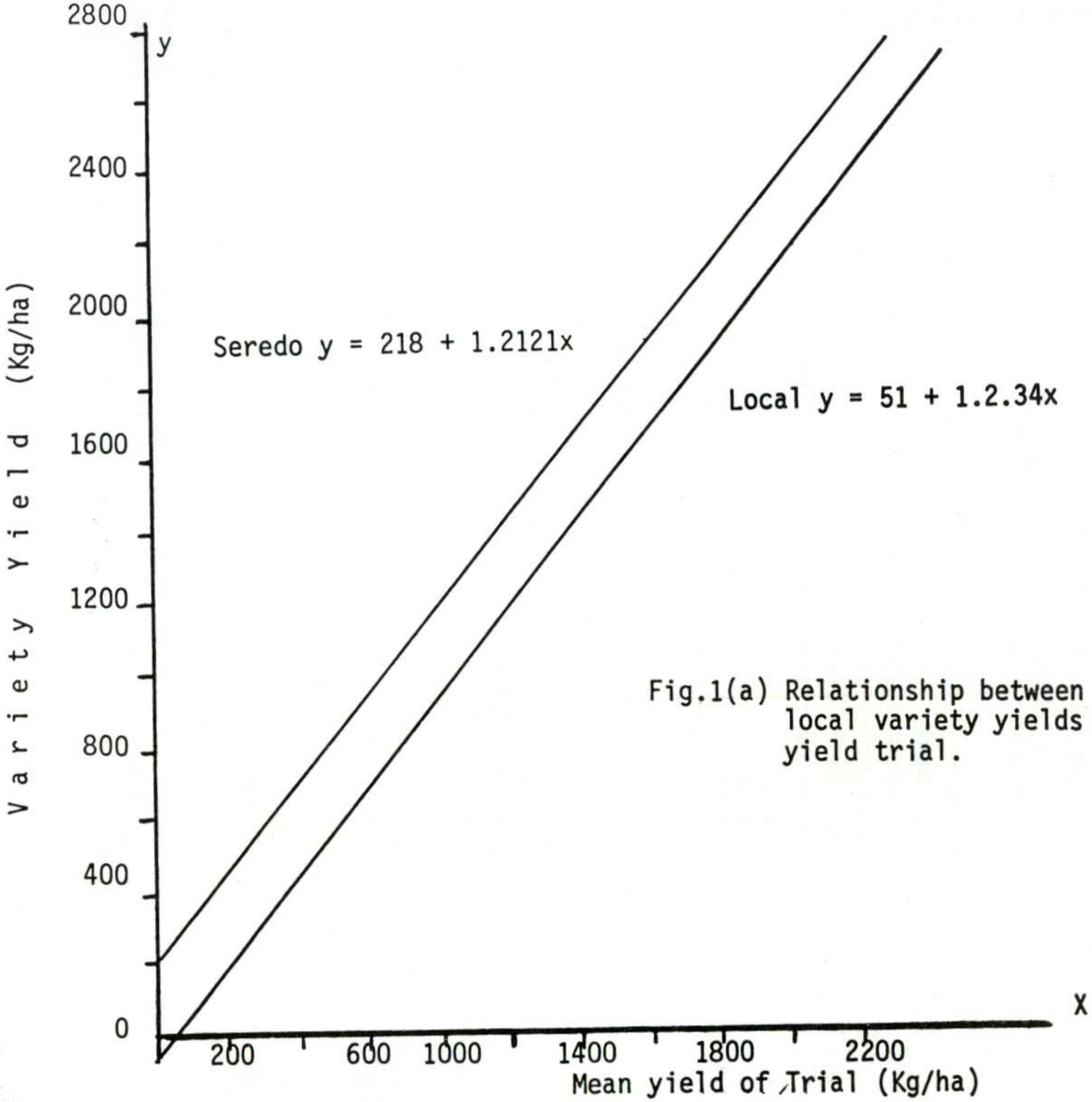

Fig.1(a) Relationship between Seredo and local variety yields and the mean yield trial.

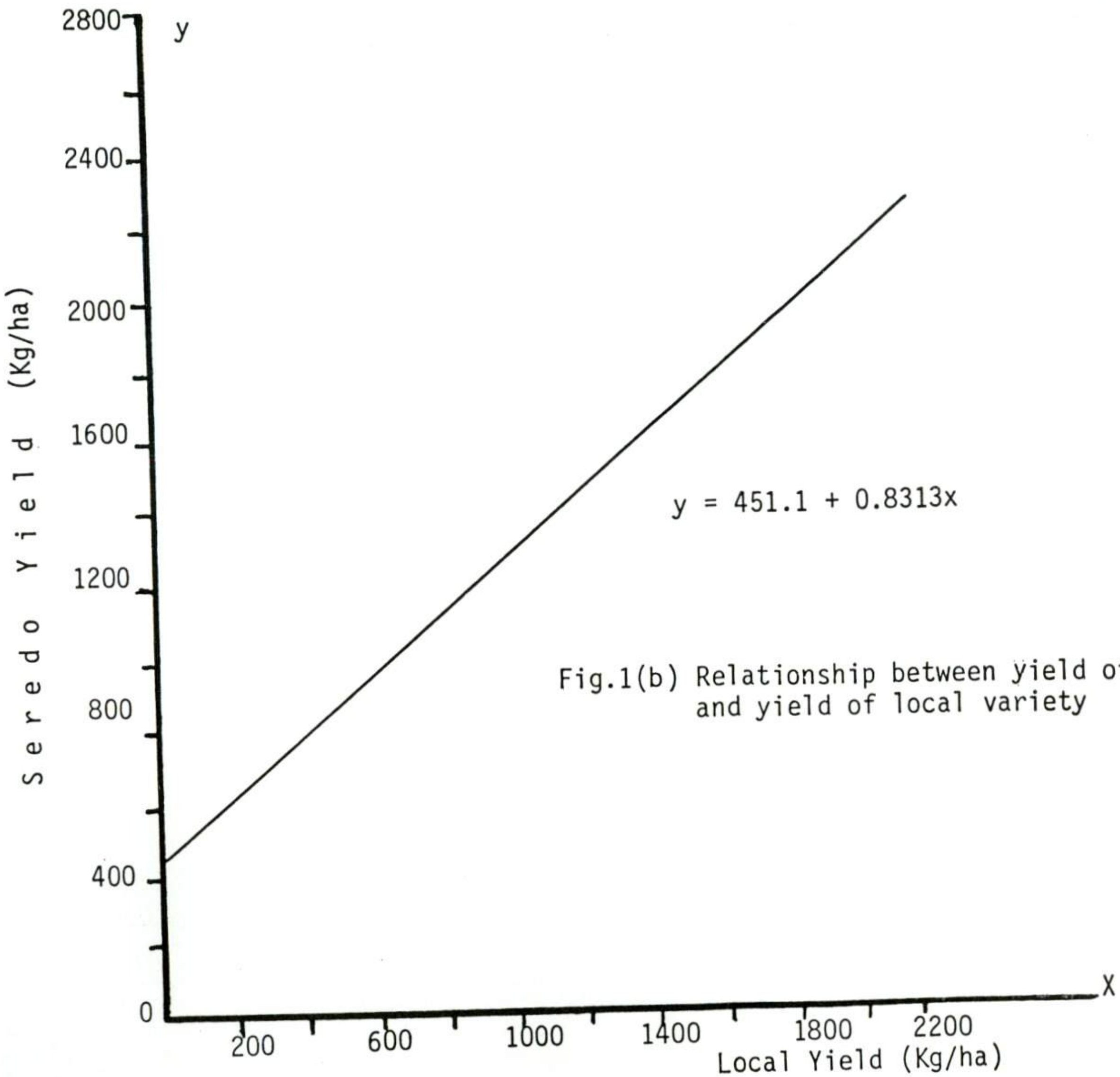

Fig.1(b) Relationship between yield of Seredo and yield of local variety

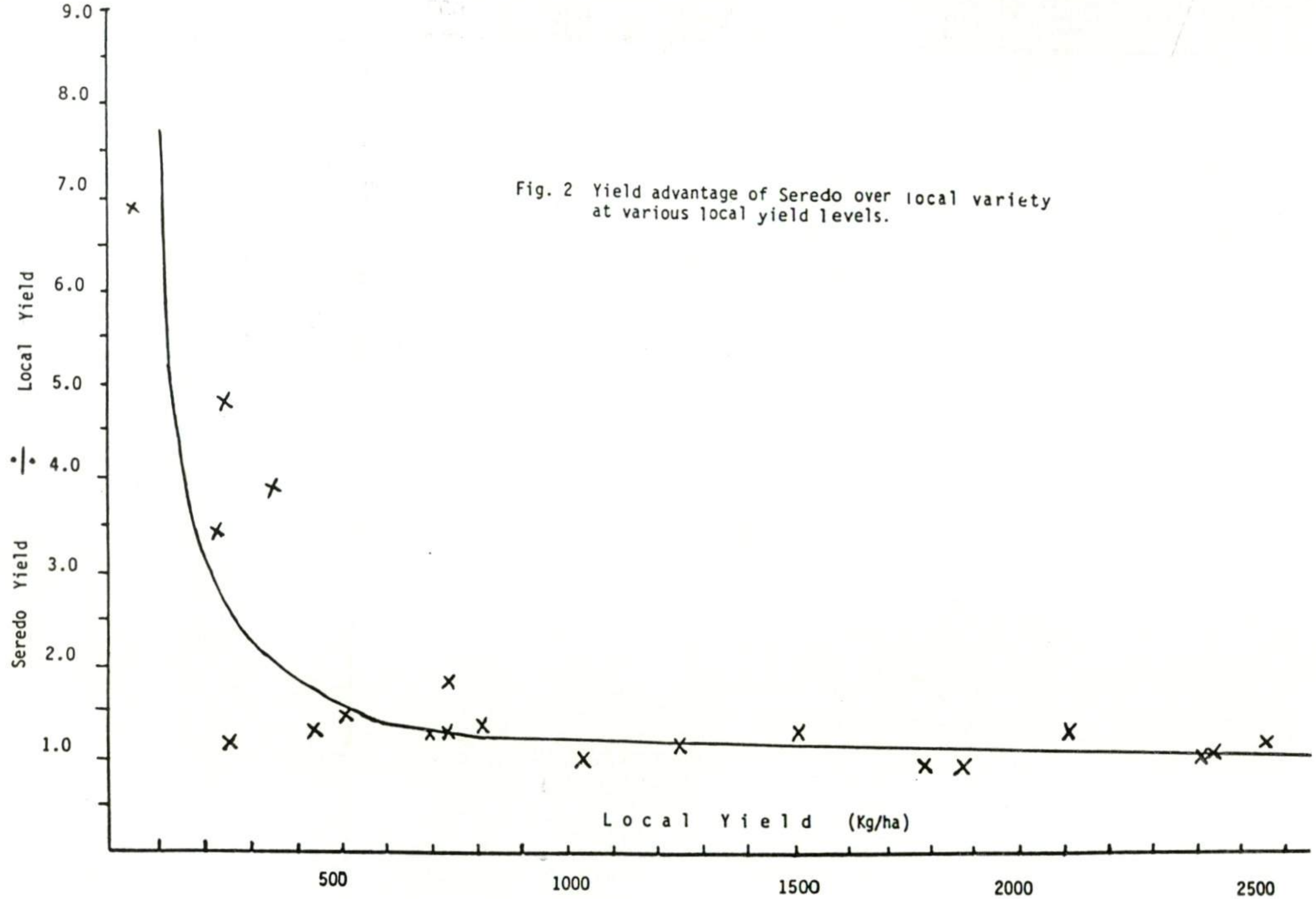

Fig. 2 Yield advantage of Seredo over local variety at various local yield levels.

Our quality targets for future sorghum varieties are:

- That they should be at least be as palatable as the commonly grown local varieties, and preferably more so, without undue susceptibility to birds;

- That they should have at least a complete ring of corneous starch in the endosperm to give some resistance to storage pests.

The following factors need to be borne in mind in interpreting the results of our yield trials:

Shoe-string project: for most of the period 1981-84, no specific funds existed for this research. It was a part-time activity of the KSS Manager, assisted by a team none of whom had secondary education. The number of sites has had to be reduced, and observations have mainly been confined to yield and quality assessment.

High co-efficients of variation: these are often recorded, largely due to moisture stress exaggerating differences in soil within the experimental area.

Poor management: especially when many sites scattered over 10,000 sq. miles are involved and where transport and time for supervision are at a premium. Late planting, delayed thinning and weeding, poor bird-scaring, etc. tend to depress yields. However, these may be positive points for the program. Karamojong farmers also encounter similar problems. Particularly interesting has been the result of the two Kaabong' trials in 1981. No weeding was done at all, and no bird-scaring. The trial was planted well after the optimum date, and thinned very late indeed. Seredo stood up to this ill-treatment better than the local variety, which is taller and more bird-resistant (Table 1).

Any seed scheme is dependent on continued variety testing, and we would like to have a broad-based on-going research program in the future. But perhaps after this year's results are in, one or two new varieties might be cautiously released for farmer evaluation and perhaps ultimate wider distribution.

As our experience with Seredo shows, good seed of productive and proven varieties is the first building block for agricultural development. It is also an extremely good financial investment for the farmer, and where Seredo is well known (e.g. around Kotido) adoption is proceeding rapidly.

Agronomy

The KAP program has included some inter-cropping studies, but much work remains to be done in this field. In addition, seed rates, tillage, plant population, weed control, soil moisture conservation, planting date and ratooning are all neglected areas of study.

As advised by dryland researchers, KAP trials have now switched from 60 cm to 100 cm rows as standard. This immediately showed a benefit in 1984 at Kaicheri where under extreme moisture stress a trial planted in 60-cm rows failed almost entirely, while another planted at 100-cm row spacing recorded no lost plots and a low but useful yield.

Though we have only informal experience to support our view, we conclude, after 12 years in the field, that a combination of good variety, early planting, row planting, early weeding and correct spacing could more than double the traditional yields in Karamoja. Ox-cultivation, by improving depth of tillage, timeliness of planting, and increasing the area under cultivation, could allow food self-sufficiency for the Karamojong in all but extreme drought years.

Another useful method of intensification is inter-cropping. In 1975 a few simple trials were conducted which should be a stimulus for further studies. Apart from increased food production per unit area of land, intercropping decreases the risk of catastrophic yield loss by drought, pests and disease. Judging by these results, sorghum is an aggressive plant, able to take advantage of the legume in a mixture (Table 2).

Finger millet

Currently, KSS is multiplying seed of the promising new Serere variety P 224. Results have been encouraging so far, and we may adopt this variety for larger-scale production if the Variety Release Committee and Uganda Seeds Project agree.

Table 2. Yields of sorghum when intercropped with various legumes in Karamoja, 1975 (Kg/ha)

Treatment combinations	Yields in pure stands		Yields in mixture		Advantage to mixture %
	Individual	Total	Individual	Total	
Sorghums	1570		2413		
and beans	213	1783	118	2531	42.0
Sorghum	1570		2461		
and grams	492	2062	396	2857	38.6
Sorghum	1570		1726		
and lablab	371	1941	1044	2770	42.7
Sorghum	1570		1562		
and cowpeas	470	2040	594	2156	5.7
Sorghum	1570		2004		
and pigeon peas	128	1698	114	2148	26.5

L.S.D.(1%) for comparing totals = 368 kg/ha
C.V. = 21.5%

Pearl millet

Ten varieties from Serere were grown in a single trial in 1972, and 12 in 1973. Differences between varieties were small, and Serere Composite 2 was chosen for multiplication largely because it is bristled and so may be adopted by farmers in areas where birds are a problem. In 1973 an international collection of over 100 varieties was planted in observation lines. Some seemed well-adapted and high-yielding but these were all non-bristled and susceptible to bird damage.

The future of research at Karamoja Seeds Scheme

On-going variety trials for sorghum and millets are obviously needed by any organization concerned with production and distribution of seed of these crops. Likewise, more variety testing for groundnuts, maize, sunflower and pulses is needed. Agronomic and socio-economic research is also needed if the best use is to be made of the varieties being produced. Unfortunately, funding and personnel are not yet available for such a program.

Acknowledgements

I would like to express my thanks to the following for their contribution to the work described in this paper:

Paul Smith for advice on statistical aspects; Eric Mahe and Boyan Love for computer-processing experimental data; the staff of Karamoja Seeds Scheme for the enthusiasm with which they worked on the trials; and my wife, Jean, for much typing, retyping and encouragement.

ACHIEVEMENTS AND PROBLEMS OF THE UGANDA SEED INDUSTRY WITH PARTICULAR REFERENCE TO SORGHUM AND MILLETS

G.G. Iputo*

Introduction

A seed industry is made up of all the complex interlocking operations that are necessary to ensure a regular supply of high quality seed to the farmer. Operations such as plant breeding and cultivar assessment, multiplication, processing and storage, marketing, certification and legislation, quarantine and seed extension are all part and parcel of a seed industry. In Uganda, these operations are carried out by institutions and organizations such as Serere and Kawanda Research Stations, the Uganda Seed Project, the Karamoja Seed Scheme, the Uganda Central Cooperative Union (UCCU), the Uganda Seed Certification Unit, and Agricultural Seed Extension and Diffusion.

Achievements of the Uganda seed industry

Cultivar release

Breeding and cultivar assessment have been successfully carried out on a number of crop varieties in Uganda. After successful field testing, a new variety has to have the Variety Release Committee's (VRC) recommendation before release for multiplication.

When a breeder has sufficient data on a new variety, he submits his application to the Secretary of the VRC for a meeting to be convened to consider his variety for release. The VRC is a technical committee made up of the following people:

a) the Commissioner for Agriculture (Chairman); b) the Director, Uganda Seed Project (Secretary); c) the Chief Research Officer; d) the Secretary Manager, Uganda Central Co-operative Union or his representative; e) the Chairman, Produce Marketing Board or his representative; f) the Dean, Faculty of Agriculture, Makerere University or his representative; g) the Senior Botanist; h) the Seed Certification Officer; and i) the Breeder.

*Foundation Seed Production Manager, Serere Research Station P.O. Soroti, Uganda.

If the committee is satisfied with the performance of the variety as compared to those already released, it will recommend its release. Meanwhile the breeder near the last year of assessment can start the multiplication of his variety on a restricted release basis himself, or use an organization such as the Uganda Seed Project to increase enough seed for further multiplication after official release of the variety.

Establishment of the Uganda Seed Multiplication Scheme

In 1969 the Uganda government launched a seed-multiplication scheme to produce and distribute certified seed of uniform and improved genetic constitution and specially prepared by processes such as chemical seed dressing, to ensure high germinability and protection against pests and diseases. The overall aim was to increase farm yields and income and therefore raise farmers' standard of living. Initially the seed scheme was to supply certified seed of groundnuts, beans, soya beans, maize, sorghum, millet, pasture grasses, and legumes.

Four classes of seed are recognized in the multiplication of seed:

1. Breeder's seed undertaken by breeders on Serere and Kawanda Research Stations;

2. Foundantion seed produced at Sendusu and, more recently, Kisindi foundation seed farms;

3. Registered seed produced on Government seed farms and by selected contract seed growers;

4. Certified seed grown by contract seed growers.

The four classes differ in field and laboratory standards of purity, germination, isolation, other crop seed, other varieties, objectionable weeds, disease-contamination, inert matter, moisture content, etc., the requirements being highest in breeder's seed and lowest in certified seed. The standards should, however, be as close as possible to those of breeder's or foundation seed. For example, recommended field isolation for open-pollinated sorghum varieties is 300 metres for foundation seed and 200 metres for certified, and no other variety of sorghum is allowed in the case of foundation seed whereas 0.01% of other varieties is allowed in the case of certified seed. After being handed over to the Uganda Seed Project or Karamoja Seed Scheme, breeder's seed is multiplied through the four classes as indicated above, the acreage progressively increasing as certified-seed class is reached.

The inspectorate section of the Uganda Seed Certification Unit conducts two field and one after-harvest of each seed lot to ascertain field standards of purity and moisture content before it is delivered for processing. A final sample of each seed lot is taken after processing, half of which is delivered to the National Seed Testing Laboratory for purity, germination and seed-health analysis and half to the trial grounds (check plots). A seed lot is certified only after meeting the field and laboratory purity and germination standards while check plots act as a reference for the field performance of any certified seed lots sold to farmers for planting. The inspectorate also ensures proper handling and storage of seed by authorized agents and distributing centers.

As with other crops, sorghum and millet production in Uganda was successful in late sixties and early seventies due to:

1. The existence of group farms and an efficient tractor-hire service which offered services to farmers at fair rates;
2. Subsidy on agricultural inputs such as fertilizers, spray chemicals, and equipment, and prizes awarded during agricultural shows which encouraged better production by farmers;
3. The availability of relatively cheap labor for most farm operations;
4. The availability of agricultural credit for expansion and development of seed farms;
5. Effective seed-distribution system through district unions and primary societies;
6. An effective agriculture extension service.

Problems of the Uganda Seed Industry

The economic and political situation in Uganda, which worsened in the seventies, reversed the Uganda Seed Industry's achievements. The tractor-hire service collapsed as tractors, tractor spares and ox-implements became unavailable and farmers were unable to prepare their land in time. Subsidies on agricultural inputs and agricultural credit were withdrawn as the Government could no longer afford these facilities for the farmer. Lack of mobility for agricultural staff and high fuel prices denied the farmer the necessary technical advice on crop production and management. Price control for seed was no longer possible as produce of any grade was marketable. The overall effect was poor seed yields low quality.

The aftermath of the war of liberation aggravated the situation, as machinery, equipment and stores on Government and private farms and factories were looted. Improved sorghum and millet seed is therefore in high demand.

Serere's role in the advancement of the Uganda seed industry

In tackling the problems hindering production, processing and distribution of cereal seeds, Serere has embarked on a foundantion seed program at the following locations:

1. On the station itself;

2. Church organizations such as Kidetok Catholic Mission and Karamoja Seed Scheme;

3. Arapai Agricultural College;

4. Prison farms around Soroti and Serere.

An agreement was reached with the church organizations such that seed is issued free and they distribute it in the course of multiplication. This seems to work well in the case of the Karamoja Seed Scheme. In the case of Arapai Agricultural College and prison farms, the agreement is that production costs are shared while Serere carries out the roguing. Depending on the costs, half the crop is recovered while the grower retains the other half. It is hoped that this approach will encourage seed diffusion as the parties concerned will sell to their neighbors.

Serere's contracts on cereal-seed production are increasing every year. In the first rains of 1985, for example, Serere estimates it will produce, 63,000 kg Serena, 98,000 kg Seredo, and 5,600 kg P 224 at the Sation and from outside contracts.

Conclusion

Some of the improved varieties of sorghum and millets have gained popularity, particularly the sorghum ones and in many parts of the country there is not enough seed to meet demand. Multiplication, processing, and distribution of large quantities of these varieties need to be mobilized by organizations such as the Uganda Seed Project, the Karamoja Seed Scheme, and Serere Research Station itself. Effective seed distribution avenues should be established in all the regions so that farmers receive seed of the right quality at the right time and place and at a fair price.

AGRO-ECOLOGICAL ZONES AND THE OPERATION OF VARIETY TRIAL CENTERS IN UGANDA

Geoffrey Ochieng Mbuye*

Uganda's climate is modified by mountains and water surfaces. There are seven distinct mountain massifs with heights of over 2,700 m, all on or near the country's boundaries. These are Muhavura and Ruwenzori in the west, Elgon, Kadam, Moroto and Murungole in the east, and Modole in the Imatong mountains to the north. Lake Victoria, the third biggest lake in the world, occupies the south-eastern corner of the country. Lake Kyoga is in the middle of the country, while lakes Albert and George are on western the borders. There are other smaller lakes in the west such as Lake Bunyonyi. The White Nile originates from Lake Victoria and passes through Kyoga and Albert before crossing into the Sudan. Another major modifier of the country's climate is the generally high altitude. Eighty-four per cent of Uganda's land surface is between 900 and 1,500 m in altitude.

Agricultural systems in Uganda

Ecologically, Uganda can be broadly divided into the tall-grass and the short-grass areas. The tall grass covers Buganda, Toro, Busoga and parts of Bukedi, while the short grass covers the rest of the country except the high-altitude areas and swamps each with their own characteristic vegetation types. The tall-grass areas mainly produce coffee and bananas while the short-grass areas, produce millet and cotton. There are two distinct rainfall peaks in Bukedi, Bunyoro, and parts of Teso, but the rainfall pattern tends to become monomodal as North Teso, Karamoja, Acholi and West Nile are approached. Karamoja and part of Ankole have a semi-arid type of climate.

Within the two major agro-ecological zones, there are eleven sub-zones, and seven major agricultural systems (Table 1). These systems are not clear-cut but they merge gradually into one another as the ecology and other controlling factors change. The agricultural systems in Uganda are a product of the fusion of the various factors governing land use. They are also a result of the social history and background of the people in the area.

---

*Scientific Officer/Cotton Agronomist and Co-ordinator of Variety Trial Centers programs in the east and north of Uganda, Department of Agriculture, Serere Research Station, P.O. Soroti, Uganda.

Table 1. Rainfall pattern, peoples and agricultural systems in Uganda, by zone

Zone	District	Rainfall pattern	People	Agricultural system
I	Busoga & Bukedi	Continuous, tending to two distinct peaks	Busoga, Japdhola Basamia Banyole Iteso & Bagwere	Banana,millet,cotton system without liners of the main coffee-banana system
II	Teso	Two distinct peaks tending to one peak in the north	Iteso	Teso system finger millet,cotton,cattle keeping, mixed culture
III	Bugisu & Sebei	Continuous, tending to two distinct peaks on plains	Bugisu and Kuksafin	Montane system, Arabica coffee, bananas, wheat and maize in Sebei
IV	Karamoja	Monomodal rainfall pattern (semi-arid)	Akaramojong,Suk and Jie	Pastoral system, cattle keeping, sorghum cultivation
V	Lango and Acholi	Two peaks tending to monomodal	Langi and Acholi	Northern system;finger millet,cotton simsim, tobacco
VI	West Nile and Madi	Mainly monomodal	Lugbara, Madi,Kukudendu and Kakwa	West Nile system, basic agriculture like V but predominance of cassava as staple
VII	Bunyoro and Toro	Two continuous peaks of rainfall	Banyoro and Batoro	Arabica and Robusta coffee,banana system;Montane system,heterogeneous agric. but basically bananas, coffee and tea

(Table 1. contd.)

VIII Ankole	Two peaks rainfall pattern semi-arid)	Banyakole	Montane system in west; pastoral to east. Arabica & Robusta coffee, tea, bananas and cattle
IX Kigezi	Two peaks	Bakiga	Sorghum, Irish potatoes, vegetables
X Lake Victoria	No distinct dry season	Baganda	Main Robusta coffee and banana system, Robusta coffee, bananas, tea, sugar and cocoa
XI Northern Buganda	Continuous to two peak rainfall peaks	Baganda & several other tribes from the East	West extension of the banana, millet, cotton system; but now largely taken up by big ranching projects.

Source: Planning cell, Ministry of Agriculture.

Sorghum and cassava now feature significantly in agricultural systems in the whole country. In the northern system, long-term sorghum varieties are grown in a mixture with simsim or pigeon peas. Sorghum is also grown in pure stands. Kigezi and Karamoja grow almost half of the country's estimated 450,000 tonnes of the cereal. In Karamoja, the crop is grown alone, while in Kigezi it is usually in a mixture with beans. Sorghum is grown in Teso and Bukedi, mainly during the second rains. It is also grown in a mixture with millet in the first rains. In the high-rainfall areas of Buganda, sorghum is grown in a mixture with beans and maize.

Variety trial centers

Variety Trial Centers (VTC), sometimes known as Agricultural Experiment Sub-Stations, were established in Uganda mainly in the 1960s. There used to be 72 VTCs in the country, but currently only 43 centers are operational. VTCs were sited strategically to present different ecological zones. These centers were set up with the purpose of:

- Utilizing them as final testing grounds for breeders' elite materials before release to farmers;

- Further testing new technologies such as pesticides and ox-cultivation;

- Utilizing them as demonstration sites for the surrounding farmers.

Administratively, there are two officers co-ordinating programs at the VTCs, one based at Serere Research Station and another at Namulonge Research Station. The officer at Serere takes care of 30 centers in the east and north of Uganda, while the officer at Namulonge looks after 23 centers scattered in Buganda and the western regions. There are a number of Assistant Agricultural Officers under each coordinator. They assist the coordinators by looking after a number of centers each. Stationed at the VTCs are the Variety Trial Observers (VTO). They are usually Assistant Agricultural Officers, Laboratory Assistants, or experienced Field Assistants. The VTCs carry out the day-to-day duties of running trials at their centers and maintaining the station.

The use of VTC is also open to Makerere University staff and to private organizations. The only condition is that these non-departmental staff are required to provide funds for labor and to provide inputs. Land is not limiting at most centers. In the past, VTC in Uganda used to handle millet and sorghum materials from the researchers in the whole of East Africa under the former East Africa Agriculture and Forestry Research Organisation arrangements. Similarly, materials from Serere used to be tested outside Uganda at the various centers in Kenya and Tanzania. With the collapse of the East African Community, the whole exercise came to an end, except in Uganda.

Problems at the VTCs

The VTCs, like many other Government set-ups, suffered serious setbacks in the 1970s due to negligence and lack of funds. The structures set up in the 1960s are still the only ones and most of them are in a very bad state of repair. Stores and drying floors require repairs or replacements. There are no means of transport to and from these centers with the result that planting materials are sent out late or not at all. The VTCs also tend to relax because of poor supervision, and experiments are sometimes written off because of poor handling. Funds for running these centers are never adequate and this causes delay in land preparation and subsequent operations. Lack of funds also forces researchers to limit the number of trials per center. Inputs and stationery are usually lacking.

Future plans

There are plans for USAID to rehabilitate VTCs. This will include repair of existing structures and/or erection of new ones and repair of fences. It will also include replacing obsolete machines and equipping offices. There is also a plan to introduce oxen at some centers to alleviate land-preparation problems. Adequate transportation will be provided for the coordinator. It is hoped that when all this is done, our VTCs, especially in the east and north, will, once more, function properly.

AN OVERVIEW OF SORGHUM DISEASES IN UGANDA

J.P.E. Esele*

Although a sorghum improvement program has been in existence in Uganda for over 30 years, little research has been directed towards the crop's pathology. This is probably because diseases had not proved to be one of the causes of yield loss in the country. There has never been a sorghum pathologist working in East Africa, and disease records were usually the work of government plant pathologists responsible for the whole range of cultivated crops (Doggett, 1978). Some of the diseases recorded on sorghum in Uganda (Doggett, 1970; Dunbar, 1969; Emechebbe, 1975) include:

1. Downy mildew, *Sclerospora sorghi* Western and Uppal), Shaw;
2. Covered smut, *Sphacelotheca sorghi* (Link) Clinton;
3. Leaf blight, *Exserohilum turcicum* Leo and Sug;
4. Rust, *Puccinia purpurea* Cooke;
5. Grey leaf spot, *Cercospora sorghi* Ellis and Everhart;
6. Anthracnose, *Colletotrichum graminicola* (Ces.) Wilson;
7. Head smut, *Sphacelotheca reiliana* (Kuhn) Clinton;
8. Sooty stripe, *Ramulispora sorghi* Ellis and Everhart;
9. Zonate leaf spot, *Gloecercospera sorghi* Bain and Edgerton;
10. Loose smut, *Sphacelotheca cruenta* (Kuhn) Potter;
11. Ergot, *Sphacelia sorghi* McRae;
12. Long smut, *Tolyposponrium ehrenbergii* (Kuhn) Patouillard;
13. Rhizoctonia root disease, *Rhizoctonia bataticola* (Tuabl.) Bult.;
14. Fusarium stalk and head rot, *Fusarium gramincarum* (Schw.) Petch.

---

*Plant Pathologist, Uganda Agriculture and Forestry Research Organisation, Sorghum and Millets Unit, Serere, P.O. Soroti, Uganda.

Today, the sorghum improvement programme in Uganda, while concentrating on the development of high yielding adaptable varieties and hybrids, recognizes plant diseases as being a potential hazard to national sorghum production. Surveys were therefore done to assess the occurrence and distribution of sorghum diseases in Uganda and also to assess their importance as potential causes of yield loss.

Materials and methods

There were two distinct areas where the surveys were carried out, at Serere Research Station and the rest of the country. There were, therefore, two different methods adopted. At Serere Research Station, all the available germplasm, consisting of all the breeding progenies and local and world collection entries,were grown out in 5-m row plots in a randomized block design with two replications. Disease occurrence was taken per plot per entry.

For the rest of the country, trips were made to selected districts which represented the various agro-ecological zones in the country. In each district, ten fields were taken rendomly, disease assessment made, and an average disease score calculated. Table 1 gives the rainfall and altitude of the various agro-ecological zones of Uganda where disease assessments were made.

Studies at Serere were made throughout the life of the crop from seedling stage to maturity while for the rest of the country, studies were made towards or at the crop-maturity period, usually between July and September. At Serere, sorghum types evaluated for diseases consisted of breeding progenies and world-collection entries, but elswhere in the country the disease assessment was done on the local land races. The assessment of disease was carried out by recording the types of diseases prevalent in the area.

At Serere, disease reaction was one of the criteria for selecting promising lines and breeding stock. From all over the country, all the local materials were collected for further study at the Serere research station.

Table 1. The Agro-ecological zones of Uganda

Zone	District	Mean annual rainfall (mm)	Altitude (m)
I	Busoga/Bukedi (Tororo)*	1,475	1,171
II	Bugisu/Sebei (Mbale)	1,145	3,411
III	Teso (Soroti)	1,311	1,123
IV	Karamoja (Kotido)	680	1,040
V	Lango/Acholi (Lira)	1,364	1,085
VI	West Nile/Madi (Arua)	1,403	1,211
VII	Bunyoro/Toro (Fort Portal)	1,530	1,539
VIII	Ankole (Mbarara)	924	1,413
XI	Kigezi (Kabale)	986	1,869
X	Lake Victoria Crescent (Namulenge)	1,264	1,148

XI	Northern Buganda (Mubende)	1,223	1,553
	Serere Research Station	1,442	1,140

Source: Planning Cell, Ministry of Agriculture.

* The mean annual rainfall and altitude data quoted were taken from the stations in brackets.

Disease score was taken using a 1-5 rating scale where:

1 = disease absent
2 = disease minor, affecting less than 10% of susceptible plant parts
3 = disease moderate, affecting 10-25% of susceptible plant parts
4 = disease severe, affecting 25-50% of suceptible plant parts
5 = disease very severe, affecting over 50% susceptible plant parts.

Results and discussion

The results showed that both foliar and inflorescence diseases occur on sorghum in Uganda. The occurrence, distribution, and incidence of the diseases is shown in Table 2.

Of the diseases observed, the most important are the smuts and leaf diseases, especially anthracnose, grey leaf spot, leaf blight and downy mildew, on the local sorghums. On the improved sorghums at Serere, grain molds are important.

Sorghum smuts

Kernel smut, loose smut, head smut, and long smut have all been reported to occur on the sorghums in Uganda (Emechebbe, 1975). Of all the smuts, covered kernel smut and loose smut were found to be the most common and probably the most serious in the country. They were particularly important in western and southern Uganda on the ratooned local sorghums. In Karamoja, the smuts were the most serious of all the sorghum diseases.

It is difficult to relate weather to smut infection because these are two extreme areas. Southern Uganda is humid and cool whereas Karamoja is hot and dry. It appears that the infection in the south arises from within the growing plant (being mostly on ratooning sorghums) while that in Karamoja is either from the soil and/or the seed.

Covered smut was also observed on the improved sorghums in Ngetta in Lira, and Labora in Gulu Variety Trial Centers (VTC) and in Kotido in farmers' fields. The occurrence of the smuts on the improved sorghums here must have arisen from infection on the local sorghums. Head smut was recorded only around Gulu town on the local variety but it was insignificant.

Table 2. Distribution and intensity of diseases of sorghum in Uganda.

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	Serere	Mean
Grain molds	2	2	2	1	2	2	2	2	2	2	2	3	2.0
Ergot	2	2	2	3	2	2	2	3	3	2	2	2	2.0
Smuts	3	2	2	3	3	2	3	3	4	3	3	2	2.8
Leaf blight	3	3	2	2	2	2	2	4	3	3	3	3	2.5
Grey leaf spot	2	2	3	2	4	3	3	2	2	1	1	2	2.0
Anthracnose	4	4	3	2	2	3	3	3	2	3	3	4	2.7
Downy mildew	2	2	2	2	3	2	2	2	2	3	3	3	2.3

Table 2. (Contd.)

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	Ser-ere	Mean
Rust	2	2	2	2	2	2	3	3	3	3	3	3	2.5
Sooty stripe	1	1	1	1	2	2	1	1	1	2	2	2	1.5
Zonate leaf spot	2	2	2	2	2	2	2	2	2	1	2	2	1.9
Bacte-rial stripe	1	1	1	1	1	1	1	2	2	2	2	2	1.4
Virus disease	2	2	2	2	2	2	2	2	2	2	2	2	2.0

Ergot

Ergot or sugary disease was observed mostly in parts of Ankole and Kigezi. The disease was severe, especially when flowering coincided with cool and humid conditions. It was also observed in Teso in the second-rains sorghum, particularly on the late planted crop. The pathogen was parasitized by Cerebella sp. making it a hard black mass which distinguishes it from smut. The infection was, however, not very widespread elsewhere.

Grain molds

Grain molds are caused by several genera of fungi. The most important of those in Uganda are Fusarium, Curvularia, Phoma, Alternaria, Colletotrichum, Helminthosporium, Aspergillus, and Penicillium. The infection has been found to be important on the improved sorghums at Serere and at VTCs, especially when the grains mature during humid weather conditions. The local sorghums do not seem to be affected by the disease. It is not clear whether these local sorghums are resistant to the infection or their maturity periods coincide with dry spells when conditions are not conducive to mold development. The improved sorghums mature early thus coinciding with the humid conditions.

Grain molds are important. They affect the grain both qualitatively and quantitatively. Seed viability is markedly reduced. The disease, therefore, poses a threat to the adoption and increased production of the early-maturing and high yielding improved sorghums.

Leaf diseases

In order of importance, the leaf diseases observed were anthracnose, grey leaf spot, leaf blight, downy mildew, rust, sooty stripe, and zonate leaf spot.

Anthracnose occurs commonly in high rainfall areas of eastern and southern Uganda. In western Uganda it occurs only in Toro but not in the cold highlands of Kigezi. It does not appear to be important in dry Karamoja and in northern Uganda. Although the degree of infection varies with the variety, the most common type is leaf anthracnose. Stalk rot also occurs and is more apparent during dry spells. At Serere, the disease is extremely serious on some world-collection entries and breeding progenies. The extent of damage by this disease ranks it as the most important leaf disease of sorghum in Uganda.

Grey leaf spot is extremely important in northern Uganda on the predominant local tall sorghum variety called Abir. Yield losses of up to 50% were estimated. The disease was not observed in areas where anthracnose is very important. The reverse also seems to be true.

Leaf blight is also important in high-rainfall areas, especially in the east and in the maize growing areas in the southern and western parts of the country. Both sorghum and maize are attacked by the same pathogen. The extent of damage by leaf blight is likely to be economically important in areas where both sorghum and maize are grown.

Downy mildew was considered to be the most important disease of sorghum in Uganda (Emechebbe, 1975). The disease is important on the sorghums grown off-season. However, on the sorghums planted early, infection is low. The systemic form of infection is the most common. As with leaf blight, downy mildew is common in southern areas where maize is grown, especially when sorghum was planted much later than the maize. It was also observed on swampy fields in the western rift valley. Many local varieties are quite susceptible. Whenever the disease occurred, the damage was serious, often resulting in marked losses in yield or no yield at all.

A bacterial disease, most probably bacterial stripe, <u>Pseudomonas andropogoni</u> (Smith) Stapp, has been observed in southern and western Uganda, but does not appear to have any economic significance. Virus infections occur almost throughout the country. They are significant in the late-planted sorghums, especially when this planting coincides with a dry spell before heading. Losses can be very high. The most common infections are by sugar-cane mosaic and maize streak viruses.

Conclusion

The distribution of sorghum diseases in Uganda follows the rainfall pattern. More diseases occur with greater severity in higher rainfall areas in western, southern and parts of eastern Uganda. Except in the case of smuts, Karamoja has the least disease problems. Smuts, anthracnose, leaf blight and downy mildew rank high in importance. Grey leaf Spot is important only in northern Uganda and bacterial diseases are only common in southern and western parts, while virus diseases are countrywide. A wide variety of diseases occur at Serere and this is attributed to the existence of a wide collection of germplasm. However, again molds rank high in importance.

Generally speaking local sorghums seem to possess a reasonable level of resistance to a number of diseases. Resistance also appears to exist in some of the collections of Serere.

A number of methods, including the use of fungicides for the eradication of and protection against pathogens, and quarantine and seed certification for the exclusion of pathogens, have always provided very effective control of plant diseases. These methods, however, are expensive and sometimes require precise operations by the farmer before any appreciable benefit can be achieved (Esele, 1983). It is therefore recognized that the cheapest methods of disease control have to be based on resistance. The level of disease resistance in breeding materials has to be maintained and exploited through screening for broad-spectrum resistance.

REFERENCES

Doggett, H. 1970. Sorghum. London: Longmans.

Doggett, H. 1978. Sorghum diseases in East Africa. In Proceedings of the International Workshop on Sorghum Diseases, 11-15 December 1978. ICRISAT, Hyderabad, India.

Dunbar, A.R. 1969. The Annual Crops of Uganda.Kampala: East African Literature Bureau.

Emechebbe, A.M. 1975. Some aspects of crop diseases in Uganda. Makerere University.

Esele, J.P.E. 1983. Sorghum research at Serere, Uganda. In Proceedings of Workshop on Crop Improvement in Eastern and Southern Africa. Research Objectives and On-Farm Testing. IDRC Regional Workshop, 20-22 July 1983, Nairobi, Kenya.

FUNGICIDAL CONTROL OF FUNGAL DISEASES OF FINGER MILLET

E.Adipala and J. Mukiibi*

Finger millet in Uganda (Eleusine coracana L. (Gaerton) is the most important cereal crop. Diseases, particularly blast, cause considerable losses in yields of finger millet (Mukiibi and Adipala, 1978). Blast (Puricularia grisea Cooke (Sac.) infection (both neck and head) results in heads remaining incompletely filled or being compeletely empty. Leaf infection by leaf blast, tar spot (Phyllachora eleusines P. Henn.) and, in particular Cylindrosporium sp. leaf spot, results in leaf necrosis and death and thus reduced yields. Unfortunately no resistant line has been identified or is being grown by farmers. Another control possibility is the foliar application of fungicides.

An experiment was conducted to find out if the important fungal diseases of finger millet could be controlled by spraying fungicides and whether or not this method of disease control would be economical. Two fungicides, Benlate (Benomyl) and Dithane M45 (Mancozeb), were selected for this experiment. Both fungicides have been reported to control blast in rice (Awoderu and Esuruoso, 1974; Dellassus, 1976) and were the most readily available in Uganda during the period of experimentation.

Materials and methods

Nine finger millet lines (P210, P226, P255, P277, P291, P304, WC142, WC277 and WC563) were selected for this experiment. Three fungicidal treatments (foliar application of Benlate (B),Dithane M45 (D), and unsprayed control (NS)) were also selected to be used on each finger-millet line. Each of the 27 line x fungicide-treatment combinations was assigned to a 3m x 1.2m plot. The experiment design used was a randomized complete block with five replications. Seeds were treated with Agrosan GN and were planted at a spacing of 30 cm between rows and 10 cm between plants. The small size of the plots was due to the limited amount of seed and fungicides available during the period of experimentation. Spraying with the fungicides at the rate of 1 kg/1000 l/ha commenced two weeks after planting and continued up to four weeks before harvesting, giving a total of 14 sprayings during the trial.

---

*Lecturer in Mycology and Dean, respectively, Faculty of Agriculture and Forestry, Makerere University, Kampala, Uganda.

Head blast was counted as the percentage of infected spikelets in 10 heads randomly selected in the middle row. Neck blast infection was recorded as the number of infected necks per plot irrespective of whether the same head also had tip (head) infection. Tar spot and Cylindrosporium leaf spot were counted as the number of leaf spots per 20 leaves, and also as the number of infected leaves per 20 plants. The mature heads of finger millet were harvested from the three middle rows, 140 days after planting.

Results

The results of the experiment are given in Table 1. Spraying with Benlate reduced leaf blast level by an average of 28%, while Dithane M45 reduced the disease level by 16%. Compared to the unsprayed control, Benlate reduced the level of spikelet (head blast) infection by 31%, while Dithane M45 reduced the spikelet infection by only 17%. Among the nine lines tested, there was no difference in the head-blast level among lines P210, P226, P304, P255, P277 and P291, but WC563 and WC277 were more infected than all the lines listed above. Both fungicides reduced the amount of neck-blast infection. Benlate reduced neck-blast infection by 31%, while Dithane M45 reduced the disease level by 22%. WC563 was more infected than P226, P210, P255, P277, P291 and P304.

Both fungicides reduced the number of tar spots with Benlate, causing a greater reduction in tar-spot infection than Dithane M45. Benlate reduced the number of tar spots by 38%, while Dithane M45 reduced the disease level by only 21%. Both fungicides reduced the Cylindrosporium infection, with Benlate giving more effective control. Benlate reduced the disease level by 56%, while Dithan M45 reduced it by 25%. There was little difference in the disease level among most of the lines.

Plots sprayed with Benlate and Dithane M45 outyielded the unsprayed control. Yields were 1,806, 1,519 and 1,120 kg/ha respectively. Benlate caused greater yield increase (73%) than Dithane M45 (46%). Line P255 outyielded all the other 8 lines.

Discussion

From the above results, the increase in yield was attributed to the fungicidal control of the diseases, since clean weeding was strictly observed and also Thiodan was used to control insect damage. A financial-return-benefit analysis showed that spraying with the two fungicides was profitable.

Table 1: Mean number of leaf blast spots per 5 plants, % infected spikelets, blast infected necks per plots, tar plots and *Cylindrosporium* leaf spot per 20 leaves and yield in grams per plot sample.

Treatment		Leaf blast	% spikelet infection (1)	Neck blast (2)	Tar spot (3)	*Cylindrosporium* leaf spot (3)	Yield (gm/plot)
P210	D	16.3	14.4	1.2	313.4	50.8	576
	B	16.6	10.6	1.0	32.8	9.5	801
	NS	18.3	17.1	1.5	2367.0	923.0	559
P226	D	16.3	13.9	1.2	534.0	41.0	861
	B	13.9	13.1	1.3	115.4	5.3	813
	NS	20.6	15.4	1.8	2208.0	156.5	348
P255	D	14.1	20.8	1.8	227.8	29.3	866
	B	13.4	16.5	1.5	132.0	11.9	1037
	NS	16.6	26.7	3.8	1352.0	156.7	775
P277	D	14.2	18.9	1.4	565.4	142.8	495
	B	10.7	15.5	1.2	166.4	7.1	693
	NS	16.5	25.6	2.8	3759.0	354.4	437
P291	D	15.3	16.7	1.2	112.8	41.0	731
	B	12.9	16.3	1.2	104.7	25.6	742
	NS	19.0	20.6	2.8	2281.0	180.0	536
P304	D	15.0	19.4	1.8	444.6	105.2	712
	B	13.0	16.3	1.0	140.4	10.8	799
	NS	19.0	21.8	2.8	1054.0	183.2	544

Table 1: (Cont'd)

Treatment		Leaf blast	% spikelet infection (1)	Neck blast (2)	Tar Spot (3)	Cylindrosporium leaf spot (3)	Yield (gm/plot)
WC142	D	14.4	25.2	3.8	527.8	101.6	379
	B	12.0	22.5	3.0	19.5	34.1	520
	NS	18.1	34.2	8.3	1086.0	343.0	289
WC277	D	18.5	30.4	7.3	754.1	133.6	406
	B	15.1	26.1	5.7	134.9	19.7	460
	NS	22.2	39.9	10.1	1158.0	223.8	197
WC563	D	17.8	36.0	17.6	186.7	28.8	310
	B	15.4	28.9	11.6	222.0	5.1	446
	NS	21.4	38.8	25.6	1225.0	220.7	237

(1), (2) and (3) = Means from inverse sine, square root and log transformed data, respectively.

Disease scores for tar spot and Cylindrosporium leaf spots were taken 87 days after planting.

" " for leaf blast were taken 35, 42, 60, 65 and 75 days after planting

" " for head blast were taken 77, 84, 91, 98, 105, 112 and 119 days after planting.

Both fungicides delayed and retarded the disease epidemics but became less efficient with increased infection. Van der Plank (1963) has explained the inefficiency of fungicides with increased disease build up on the basis of the fungicides having a harder task to perform in the sprayed plots than the control plots because the fungicide-protected plots become heavily contaminated from the unsprayed plots and thus contribute to the "cryptic error" which, in effect, underestimates the efficiency of the fungicides. However, in all cases Benlate was superior to Dithane M45 in controlling the diseases and increasing yield. Dellassus (1976) working in Senegal also found 2-4 applications of Benlate, Thiophenate and, especially, Edifenphos to increase paddy yields markedly as a result of the very good control of blast. Similar results were reported by Ribeiro (1974), and Rodriquez *et al.*(1974). On the other hand, in bananas, Guyon (1971) found Dithane M45 and anthocol (10% probineb) to be more effective than Benlate, Difolitan and Thiodan in controlling *P. grisea*. Awoderu and Esuruoso (1974) working in Nigeria also found Dithane M45 increased yield and reduced blast infection on rice. It was concluded that the performance of Benlate and Dithane M45 is influenced by location and type of crop. It was also found that sprayed plots had bigger and more numerous grains/spikelets compared to the unsprayed control, suggesting that the gain in seed yield as a result of spraying was due to more seeds forming and filling fully.

It was observed that although P255 recorded a high spikelet infection, the line still gave high yields. This might have happened because the neck-blast incidence in P255 was comparatively less than in most of the other lines in the study. In all cases, the highest response to fungicidal applications appears to be from the most infected lines. On the average, P304 was least infected and its yield potential was good, but it had the disadvantage of severe lodging. P255 was the highest yielder, while WC563 and WC277 were the two lines most affected by blast.

Summary

Spraying finger millet with Dithane M45 and Benlate controlled fungal diseases and increased seed yield. In all cases: (a) Benlate was superior to Dithane M45, (b) Benlate and Dithane M45 increased yields by 73% and 46%, respectively, and (c) both fungicides controlled head blast, neck blast, *Cylindrosporium* leaf spot and tar spot but were largely ineffective in controlling leaf blast. Because of the reported ability of fungi to develop resistance to Benlate, a cocktail mixture of the two fungicides was recommended.

REFERENCES

Awoderu, V.A. and Esuruoso, O.F. 1974. Reduction in grain yield of two rice varieties infected by rice blast disease in Nigeria. Nigerian Agric. J. 11(2): 170-3.

Dellassus, M.1976. Chemical control of Pyriculariosis of rain-fed rice in Casamance (Senegal). Field Crop Abstract 29(5): 333.

Guyon, M. (1971). Essais de lutte contre la"Johnson fruit spot" au Nicaragua. (Fungicidal trials against "Johnson fruit spot" in Nicaragua). Review of Plant Pathology 50: 427.

Mukiibi, J. and Adipala, E. 1978. Finger millet diseases with special emphasis on blast disease. Report on the improvement of sorghum, finger millet and pigeon peas, Phase II, April 1977 - June 1978. Makerere University, Department of Crop Science, pp.7 - 11.

Ribeiro, A.S. 1974. Control of blast with fungicides. Field Crop Abstract 27(10): 515.

Rodriguez, V.A.E. and Rodriguez, S.H. 1974. Evaluation of fungicides for the control of rice blast. Field Crop Abstract 27(9): 462.

Van der Plank, J.E. 1963. Plant Diseases, Epidemics and Control. New York and London: Academic Press.

DIFFERENCES IN RESISTANCE TO THE RICE WEEVIL IN SORGHUM

C.D. Muhwana*

One of the worst disadvantages of sorghum as a grain crop is its relatively poor storage ability. The crop succumbs easily to attack by storage pests, among which is the rice weevil, *Sitophilus oryzae* (L.). Although several measures, including proper sanitation and chemical control, are available for the control of these pests, there is growing hope that it can also be controlled by use of genetically resistant lines of sorghum. The results of an investigation on the reaction of sorghum lines to the rice weevil are reported here.

Materials and methods

Fourteen sorghum lines, including Serena as a local check, were used in this investigation. Twenty grams of grain from each line were placed in separate plastic vials and corked. Test insects were obtained from bulk seed comprising 50 grams of each line to be tested. Four female and two male weevils were introduced into each vial and four replications were made. The experiment was repeated four times on different dates. Per cent mortality, reproductive potential and per cent damaged seeds were recorded. Also recorded, was the interaction between mortality and number of damaged seeds over a period of time.

Results and discussions

The preliminary results indicate that Pop./11/30, 2KX 190/10/1, Red Flint, Pop./10/1 and 2KX 196 have high resistance to this weevil as indicated by the high mortalities, low reproductive rates and less damaged seeds (Table 1). Line 2KX 196 reacted in a rather unexpected manner by having a high percentage of damaged seeds despite the high mortality and low reproductive rate of the insects.

---

* Cereal Entomology, UAFRO, Serere, Sorghum and Millets Unit, P.O. Soroti, Uganda.

Table 1. Effects of different types of grains on the rice weevil

Entry	% mortality	Number of weevils	% Damaged Seed
Red Flint Pop./10/1	71	1.14	25
Red Flint Pop./1	75	1.18	21
2KX 190/1	82	0.63	24
2KX 71/1	46	3.29	42
Lulu Dwarf	47	2.31	30
Pop.11/30	83	0.57	21
Himidi	34	4.00	43
2KX 43 Short	47	3.14	32
Pop./11/27	74	1.38	26
Serena	32	4.18	35
2KX 196	80	0.81	40
2KX 19 Tan	73	1.38	25
2KX 191/1	41	3.67	31
Pop./11/2	73	1.30	26

Table 2. Decrease in per cent mortality of the rice weevil with increase in time

Entry	Percentage mortality				Mean
	7 days	19 days	28 days	56 days	
Red Flint Pop./1	50	13	8	1.3	18.08
Red Flint Pop./10/1	66	42	8	0.9	29.73
2KX 190/1/1	46	29	0	3.3	19.58
2KX 71/1	17	8	0	1.0	6.50
Pop./11/2	21	8	13	2.4	11.10
2KX 196	50	33	4	2.4	22.35
Pop./11/27	63	13	0	1.7	19.43
2KX 43 Short	13	17	17	0.7	11.93
2KX 191/1	46	13	0	0.4	14.85
2KX 19 Tan	33	25	8	1.5	16.38
Pop./11/30	25	38	25	3.2	22.80
Lulu Dwarf	25	33	8	0.4	16.60
Serena	21	21	17	0.2	16.80
Himidi	8	21	8	0.8	9.45

Table 3. Increase in per cent damaged seeds with increase in time

Entry	Per cent damaged seeds 7 days	19 days	28 days	Mean
Red Flinty Pop./1	4	8	9	7.00
Red Flinty Pop./10/1	7	8	10	3.33
2KX 190/1/1	5	8	11	8.00
2KX 71/1	11	12	18	13.67
Pop./11/2	8	9	9	8.67
2KX 196	9	13	18	10.33
Pop./11/27	6	9	11	8.67
2KX 43 Short	10	10	12	10.67
2KX 191/1	10	7	14	10.33
2KX 19 Tan	6	9	10	8.33
Pop./11/30	7	8	6	7.00
Lulu Dwarf	7	9	14	10.00
Serena	9	16	10	11.67
Himidi	14	16	17	15.67

When the effect of the time factor on the survival of the weevil was investigated, there was an indication of an interaction between time and resistance, affecting the chances of survival by the rice weevil. Mortality was high during the first week of infestation and it progressively decreased from thereafter. Tables 2 and 3 indicate that with increasing time more seeds were damaged and consequently survival of the weevil improved.

BIRD-PEST RESEARCH AND CONTROL STRATEGIES ON CEREALS IN UGANDA

F.H. Okurut Akol and R. Molo*

Farmers in the drier parts of Africa face substantial losses of their ripening cereals to bird pests, particularly *Quelea quelea*. Since time immemorial, flocks of these birds have sporadically raided fields of sorghum and millets (Ward, 1973). There are three known species of *Quelea* in this region, the red-billed quelea (*Quelea quelea*), the cardinal Quelea (*Quelea cardinalis*), and the red-headed quelea (*Quelea erythrops*).

In East Africa, losses of cereal crops to birds were estimated at a minimum of US$ 15 million (Elliot, 1981), the *Quelea* being the major depredator. Damage is sporadic and varies from place to place within the same region or country. Therefore, an overall impression of the damage cannot be formed for the whole region. To get an overall picture, intensive damage assessments over a long period of time need to be carried out.

The bird pest situation and cereal crops

The bird-pest problems in Uganda appears to be more complicated than in the rest of eastern African and varies from season to season and place to place (Ash, 1983). Elsewhere, quelea are the main problem and their gregariousness makes it possible to advise effective control techniques. In Uganda, however, a wide range of grain-eating bird species affects a variety of crops on many small farms over large areas of the country. The potential pests are also numerous. Within the Ploceidae, 61 species are recorded and these include 10 *Euplectes*, 25 *Ploceus* and 3 *Quelea*. Of the 25 *Ploceus*, 10 are considered to be capable of causing substantial damage to cereals, 9 cause moderate damage, and a further 6 a lesser amount of damage. Besides, there are many other species in other genera and families which cause damage to cereals. *Quelea* are more widespread than was originally thought, and the first breeding colony was located at the shores of Lake Kyoga at Labori in Uganda.

---

*Vertebrate Pest Unit, Serere Research Station, P.O. Soroti, Uganda.

The main factor hindering a quantitative estimate of damage due to birds is the traditional methods of agriculture practised in much of the country. A variety of cereals are grown on small family farms and normally mixed: millet with maize, millet with sorghum and sometimes with more than one variety of each mixed crop. There is also a prolonged planting period resulting in some crops surviving bird attack. Furthermore, there are different bird-pest species which are active at different times in the same area. Estimates of grain losses can, however, be readily obtained in marginal farming areas like Karamoja or on large monocrop areas such as Kibimba Rice Scheme. In Kibimba, yield losses of rice were estimated to be about 15% for one season in 1983.

Bird-pest research and control strategies

Bird resistance breeding in cereals

In breeding for bird resistance in cereals, the useful characters include long or large glumes, long and stiff awns, pendent head, and non-palatable and large-sized grains. Other characters include dense panicle, short straw with uniform height and early maturity.

Agronomic practices

The agronomic techniques which should be looked into in order to try to reduce bird damage include crop substitution, crop dilution, crop diversity, crop diversion and crop husbandry.

Traditional methods

Traditional methods of control include trapping, use of disturbing auditory devices, capture, throwing missiles, etc.

Repellents

Repellents are chemicals which can be applied directly on to the crops so as to repel the birds which damage them. The birds are discouraged from feeding on that crop and can sometimes make distress calls to warn-off others. An example of a repellent is methiocarb.

Lethal control

This technique involves the use of avicides like Fenthion. They are sprayed in the roosts or colonies of bird pests using ground sprayers or aircraft.

Discussion and conclusion

Despite the major efforts in bird-resistance breeding in Uganda, no single character was observed to effectively reduce bird damage in sorghum (Doggett, 1970). In sorghums with long glumes, birds like weavers, which have powerful beaks, can squeeze the grain out of the glumes. Neither were the stiff and spiny awns on the sorghum heads found to be sufficient protection against birds. Pendent head is a character which is useful when the birds have a choice but it is not so useful under high bird pressure.

Some varieties of sorghum, though eaten by birds, are less palatable than others. Unpalatable types of sorghum, which usually have brown seeds are least preferred by birds. In the absence of any other food, however, hungry birds also eat brown sorghums. Sorghum varieties with dense panicles are less damaged than those with open heads. Bird scaring is easier in a field of sorghum with short uniform straw. Early maturing varieties can be planted to avoid damage. Despite the various efforts in breeding sorghum for bird resistance, incorporation of all the desired characters in individual plant varieties has so far been unsuccessful.

Most of the agronomic techniques which can be used to reduce bird damage have been practised by farmers at one time or has forced farmers to grow maize in unsuitable dry areas. In other cases, crops are mixed with more of the less preferred types. Fields free of weeds keep off birds which might be attracted by wild grass seeds. A knowledge of the crop calendar would also allow crops to mature when birds are away or their attention diverted to wild grass seeds available in the area. It is, however, difficult to implement this since variable factors such as weather are the major controlling agents. In order to successfully carry out any of these agronomic techniques, the bird ecology, behaviour and feeding habits need be known fully.

Traditional methods have always been used and are still largely used in Uganda and elsewhere. Although they vary from culture to culture they include slings, flexible sticks to propel wet clay, beating empty tins, trapping with lime from Ficus trees, catching birds in night roosts or the young in breeding colonies, flags, scarecrows, etc. These methods are cheap for the subsistence-level farmer and they have continued to be used because they are associated with traditional agriculture. However, with children now in school, no labor is available for bird scaring and the problem has therefore remained unsolved.

Lethal control methods have resulted in hundreds of millions of birds being killed in Africa every year. Where the birds have been destroyed, reduction in crop damage has been noticed. The strategy of lethal control advanced by Ward (1973) advocates the destruction of birds in areas near or where there are vulnerable crops and at the time of the year when the crops are at a vulnerable stage. The advantage of lethal control is that a good number of the birds in the target area is destroyed. Lethal control is, however, detrimental to the environment. In cases of breeding colonies at the shores of Lake Kyoga in Uganda, for example, widespread or widescale aerial application of avicide would definitely pollute the water and fish would be at risk. Where there are scattered and isolated cases of colonies of bird species like Ploceus cuculatus and Ploceus rubiginousus, which are common in Uganda, ground spraying is recommended and the advantage is that the avicide can be directed right onto the target. The cost-benefit effect of the lethal method of control has to be evaluated before undertaking control operations.

Lastly, the success of research involving incorporation in individual plants of all the biochemical and morphological characters mentioned would greatly reduce bird damage to cereal crops. Integration of bird resistance with other control methods will help minimize the bird problem.

REFERENCES

Ash, J.S. 1983. Preparatory assistance for establishing a grain-eating-bird control unit. Technical Co-Operation Program for Uganda. Project Findings and Recommendations. FAO, Rome.

Doggett, H. 1970. Sorghum. Tropical Agriculture Series. London: Longmans.

Elliot, C.C.H. 1981. An assessment of the bird pest problem in Sudan, Ethiopia, Somalia, Kenya and Tanganyika. FAO, RAF/77/042.

Ward, P. 1973. A new strategy for the control of damage by Quelea. PANS 19(1): 97-106.

PRESERVATION OF BULK-STORED SORCHUM THROUGH AERATION USING SOLAR-COOLED AIR: A NON-CHEMICAL APPROACH

Wilfred R. Odogola*

Food grains such as sorghum and millet are dried in order to prevent germination of the seed, retain maximum quality and reach a level of moisture which not only prohibits the growth of bacteria and fungi but also insects. It is evident, however, that even with well dried food commodities such as cereal grains and pulses stored in bags or in bulk, insect pests, mites and moulds may cause portions of the crop to heat up. This well-documented phenomenon, (Hall, 1970), results in convective moisture migration from warmer to cooler regions of the store, thus causing serious spoilage. If left uncontrolled, stored-product insects and moulds can destroy stored grain, particularly sorghum, within a matter of months. The effect is more pronounced in moist tropical climates with optimum conditions for the insects' population development throughout the year.

Such a situation is aggravated by poor storage facilities where the crop may be exposed to migrating insect pests, fluctuating temperatures and/or occasional re-wetting by rain. This aggravates attacks by insects and moulds and causes sprouting in the stored crop.

Post-harvest losses in sorghum and millet

A cursory review of food grain-harvesting, processing and storage methods in tropical Africa (Hall, 1970; Commonwealth Secretariat, 1977 and 1978) suggests that considerable losses, both in quantity and quality, occur at all stages of the post-harvest system. These range from the losses caused on the standing crop by harsh weather conditions (rain, heat, wind, etc.) to destruction by birds and rodents and, finally, to the losses incurred during harvesting, transportation, processing and storage of the crop.

---

*Agricultural Engineer, R & D, National Co-ordinator, Solar Crop Drying Project, Serere Research Station, P.O. Soroti, Uganda.

In most African countries, although no intensive scientific studies of these losses have been made with respect to sorghum and millet, it is generally accepted that the losses inflicted on the crops by storage insects are greatest. In this connection, a team of FAO experts (FAO, 1971) estimated that 80% of stored food grain can be attacked by insects after a 4 - 5 month storage period, resulting in a 10 - 15% loss of food. In certain circumstances losses as high as 50-60% have been reported to occur over a 6-month storage period, particularly in soft endosperm varieties of sorghum. Table 1 gives loss/damage figures of some agricultural produce in selected African countries as a result of stored-product insects.

Table 1. Food grain losses (L) or damage (D) for selected African countries after 4 - 12 months' storage.

Country	Commodity	Where stored	%loss/ damage	Major course
Senegal	Groundnuts	Co-op. Store	20-30 (L)	Insects (Caryedon)
	Millet	Farm	20-50 (L)	Insects (Trogodema) and rats
	Sorghum	Farm	15-20 (L)	Insects (Sitotroga) and rats
	Cowpeas	Farm	23-56 (D)	Insects (Bruchidae) at harvest
Uganda	Maize	Farm	50 (L)	Moulds and insects (Sitrophilus)
	Groundnuts	Farm	20 (L)	Moulds and insects (Sitrophilus)
	Beans	Farm	80 (D)	Insects (Bruchids)
Zambia	Maize	Farm	10 (L)	Rodents
	Maize	Farm	70-80 (D)	Insects (Sitrophilus)
	Sorghum	Farm	10 (D)	Insects (Sitotroga and Sitrophilus)
Kenya	Maize	Farm	10-15 (D)	Insects
	Maize (imported)	Board Stores	17	Shrinking
Nigeria	Millet	Farm	50 (D)	Insects (Sitotroga)
	Sorghum	Farm	15 (L)	Insects (Sitotroga)
	Cowpeas	Farm Market	60-70 (D)	Insects Bruchids)

Source: FAO, Rome, 1971.
Notes: Loss = % weight loss; damage = % grain affected by pests.

Improving storage and marketing of the cereals to ensure a whole-year-round supply of crops to the various sources is important. This emphasizes the importance of eliminating moulds which can make the grain toxic and discoloured, and insect pests, which can substantially reduce the nutritive value of the food grains.

Preservation through solar-cooled air

Below a certain minimum threshold temperature, mites, fungi or insects cannot complete their life-cycles and the pest population cannot increase. At a temperature only slightly above threshold, say, within 4-5^{0}C, mortality rates are extremely high for virtually all stages of the pest. Most species do not multiply fast enough to become a pest until some 3-6^{0}C above the minimum threshold for development. Food grains such as sorghum stored in bulk can effectively be preserved through aeration using solar-cooled air (Odogola, 1984). This technology is particularly appropriate for the climates of East Africa, i.e. moderately high temperatures (mean annual max. 22-30^{0}C) and low ambient relative humidity (65-80%) during the day with fairly cold (mean annual min. 14-17^{0}C) nights and very high relative humidity (80-100%) with these conditions prevailing almost all year round.

With this technology, ambient day-time air is passed through a flat-plate collector where it is heated up for effective drying of an appropriate desiccant, e.g. silica gel (or maize seeds) down to a moisture level of, say, 3-4%. Thereafter the air is let free into the atmosphere or profitably used as a drying fluid for some crop. During selected periods of the night, cold and moist ambient air is passed in the opposite direction, first through the desiccant bed, where the loss of moisture to the gel, causes a slight rise in air temperature of approximately 1^{0}C. Proceeding through the collector(s), heat is lost by the air to the atmosphere through infra-red-wave radiation in accordance with Hottel's (1976) equation. It is estimated that under most east African climatic conditions, this can cause a drop in air temperature of up to 50^{0}C. After the collector(s), the resulting cold but dry air is passed through the stored grain.

Continuous operation of a fan will maintain the grain temperature at 13-14^{0}C. This is well below the 15-16^{0}C insect-control threshold temperature which only eliminates temperature differentials that cause moisture migration within the grain, but also prevents further multiplication of most stored-product insect pests and rodents which may be present when chemical control is not employed.

Studies carried out at the CSIRO Department of Agricultural Engineering, Highett, have demonstrated the feasibility of obtaining bulk-grain temperatures that would be low enough to prevent, or at least severely restrict, the reproduction of most storage pests (Odogola, 1984). The climatic conditions where the studies were made were similar to those of eastern Africa. The equipment used for achieving this is simple and can easily be fabricated using locally available materials. The maintenance and running costs are also very low being mainly the cost of energy to run the fan used to agitate the air through the system. This is rated at 0.15 - 0.20 kw per ton of stored grain approximately.

Conclusion

Besides increasing crop yields, major efforts must be made to save what has been harvested by protection against pests, and by improving local processing methods to retain the inherent natural nutritional value of the product. Grain preservation through solar cooling is one of the important methods of achieving this goal. With better grain preservation techniques, the farming population is assured of better returns for their labor. This development stimulates productivity and ensures sustained food supply to the entire nation.

REFERENCES

Hall, D.W. 1970. Handling and storage of food grains in tropical and sub-tropical areas. FAO, Paper No. 90; Rome.

Commonwealth Secretariat. 1977. Storage losses of foodgrains in Commonwealth Africa. London: Commonwealth Secretariat.

Commonwealth Secretariat. 1978. Report of the First Regional Grain Conservation Seminar, Lusaka, Zambia. :London: Commonwealth Secretariat.

FAO. 1971. Report on a project formulation mission on farm Grain storage in Africa. FAO, Rome.

Hottel, H.C. 1976. A simple model for estimating the transmittance of direct solar radiation through clear atmospheres. Solar Energy 13: 129.

Odogola, W.R. 1984. Preservation of grain through solar drying and cooling. Fellowship Attendance Technical Report to the Commonwealth Foundation, London.

ALL PAPERS ON UGANDA DISCUSSION

Rowland

In 1983 the sorghum hectarage overtook that of maize. Is this likely to be a continuing situation?

Zake

Weather conditions might have dictated this. It must have been the farmers' response to the prevailing weather situation. It is not easy to know whether the trend will continue.

Brhane

Serere Composite 2 has been found very useful under a wide range of conditions in Africa. What is the background and the components of this composite?

Odelle

From the records I have with me, SC 2 consists of materials of the Serere Collection. I am not sure of the sources of the latter because pearl millet is a fairly new crop in Uganda.

Rai

In my opinion, Serere Composite 2 is not entirely based on germplasm from Uganda. Judging from the plant type and seed size, it seems to have involved some germplasm of Togo/Ghana land race types.

Oryokot

What is the relationship between maturity time and altitude? Is it possible to categorically describe maturity time and altitude?

Zake

Comparing a named variety to varying altitude, it flowers earlier at lower altitudes. It is not, however, possible to categorize maturity time and altitude because with a similar altitude there is genotypic variation and what I consider important is the use of multilocation sites for selection of suitable variety adaptable for the specific altitude.

Brhane

It is well known that a given variety will mature earlier if it is grown in warmer and lower altitudes. The major factor enhancing earliness seems to be higher temperature. Differences in maturity can be meaningfully considered for a specific ecological or altitude zone.

Yilma

How far do you think you can go with high-altitude Ethiopian materials crossed to CK 60 A and other male-steriles, considering the great disparity in flowering time between the two sets of materials?

Zake

This has been possible through staggered planting and forced nicking and also, due to the lower elevation of Serere compared to Ethiopia, the Ethiopian materials flower comparatively earlier at Serere.

Brhane

Your list of introduced sterile sorghum lines includes R lines such as IS 84 and CSV-2. Could you let us know if this was done by mistake?

Zake

The materials listed consisted of both steriles and R-lines. However, they were sslected from ICRISAT fields and brought by one of our officers. It is very possible that labels were mistakenly interchanged. I observed further that I do not have the B lines for them, which tends to confirm suspicion.

Brhane

What is the origin of the sorghum variety name "Serena"? Is there any connection between the variety name and that of Serena Hotel in Nairobi?

Doggett

The hotel was built after Serena was released. The name Serena starts with "Ser" for Serere and the word "serene" conveys a sense of peace and well being. There may well be a word "Serena" in one of the romantic languages.

Mwaule

Population is high in Kigezi and so is the altitude. While food supply is in short are you developing any suitable sorghums for this area?

Zake

We started a project last year to specifically develop varieties for Kigezi.

Doggett

Dr Brhane, would you comment on the similarity between Rwanda and Kigezi?

Brhane

The two areas are very similar. Materials from Rwanda could be obtained for the high altitude areas of Kigezi. This is one of the objectives of the ICRISAT/SAFGRAD Cooperative Program - to promote and encourage breeding-material exchange among the national programs of the region.

Khizzah

How do you keep your seeds in the pure from and avoid outcrossing?

Rowland

By emphasizing to farmers that they must comply with our requirements such as growing in isolation and hand roguing before flowering, but we have no way of certifying the purity of our seeds.

Taye

Is tied-ridging used in Uganda as a measure of water conservation?

Akou and Mwaule

This was tried in Namulonge with maize but was stopped. The ractice was also tried with grass bands but was abandoned.

Omolo

This was a typical example of inapproriate technology - one which cannot be applied in Uganda because rain shortage is not a major problem. In order that an agronomic package be acceptable to farmers, it must be appropriate to the area in which the package is being offered. Farmers must be consulted and their views incorporated into the technological package.

Oryokot

One of the possible reasons for failure in the adoption of improved varieties is the fact that these varieties demand inputs at levels they and what the farmer can afford. For technological packages to be acceptable, understanding the circumstances under which local farmers operate is essential.

Kanyenji

What do you think favours the dominance of Eleusine africana following over-cultivation with finger millet? At such a time you would expect much of the soils nutrient capacity to have been exhausted by the finger millet. Do you think that in the initial stages finger millet could have an inhibitory effect discouraging their infestation? Has an attempt been made to incorporate the good response to low fertility in these weeds to finger millet through crossing?

Koma-Alimu

The dominance of the weeds is attributed to high seed yield, leading to heavy seed build-up, storage of seed at various depths at ploughing and better competition for nutrients and light. In all fallowed land, the wild millet population may be less than 1%. Most Ugandan farmers plant finger millet as a second crop after cotton. The rapid multiplication of the wild millet and possible successive generations must make the wild millet more and more competetive with the crop. There is no evidence that this weedy relative of finger millet is resistant to soil infertility.

Brhane

Ox-cultivation has been practised in Ethiopia since ancient times. Have you had an opportunity to use or try the Ethiopian oxen plough?

Akou

No, I have not tried any and it has not been recorded anywhere here, possibly due to different vegetation or lack of contact between the two nations on this issue.

Brhane

The Ethiopian ox-drawn plough is used in wide ranging-soil and vegetation types and I would think this Ethiopian experience could be useful in selected Ugandan conditions.

Adipala

In actual fact, the ox-plough Max IV, which was developed at Kabanyolo University Farm, was a modification of the Ethiopian and South African ox-ploughs, so Ethiopian ox-ploughs have actually been used in Uganda.

Oyiki

The Ethiopian plough was tried in Southern Sudan (Torit) in 1978/79. However, it never took off due to its poor land-preparation ability under the tall-grass conditions. It was effective for opening furrows for planting groundnuts. Since farmers need the ox-plough mainly for land opening they would rather save enough money to buy a metal ox-plough.

Alahaydoian

Do you know of any line of sorghum with genetic resistance to smut?

Esele

I have not been deeply involved in studies on smuts in sorghum. This is because the disease occurs mainly on local sorghums My interest so far is to work on probable disease obstacles on the improved sorghums which at the moment are grain molds and anthracnose. I have not heard of any line possessing genetic resistance to smuts.

Khizzah

In your paper you recommended, or suggested, that the last spray should be done at about 95 days after planting. I wonder how economical this would be in view of the fact that by this time grains are filled and damage by blast, especially the neck, is already accomplished. I would suggest that the most appropriate time should be between 65 to 80 days. What is your comment on this?

Adipala

When to start and when to stop spraying will depend on (a) crop- growing period, and (b) the disease epidemology. Leaf blast attacks about eight weeks after planting and becomes more severe about three weeks before flowering. The first spray should, therefore, be before this period. It must then be sprayed at flowering to protect against head blast and Cylindrosporiumleaf spot. This disease sets in two to three weeks after heading, so that last spray should be at this stage. The actual period for spraying will, then, be determined by the crop's growing period. My recommendation of 90 days is based on average maturity of 140 days. Certainly, in your case of 100-120 days maturity period, the last spray should be earlier.

Khizzah

Are there differences in races of blast?

Adipala

Yes; for fungal blast, parts of the same plant may be infected by different races, even within nearby lesions. However, in most cases, it is the same race that attacks the same plant. Variability between races is more common on a location basis.

Frederiksen

How economical is the chemical control of finger millet disease?

Adipala

It is economical, especially if the crop is grown on a large scale. However, seed dressing is more feasible. Chemical control is also essential for promoting disease resistance over a long period of time.

Frederiksen

Do you have joint training and research programs between the University and research institutions in Uganda?

Adipala

We have a number of joint research programs, all conducted under the co-ordination of the National Research Council. We also share a lot of research materials, such as working germplasm. However, there is a need to strengthen these ties.

Adipala

Are there some slow-release formulations of fungicides being used outside Uganda? How much research work has been done on such formulations?

Frederiksen

Research is being carried out on the slow release of fungicides, particularly for the newer systemic products. None are marketed at this time.

Alahaydoian

After so many years of fighting against quelea, what has been accomplished? Has anybody done an appraisal?

Omolo

Most of the methods used are very expensive. Population reduction is the only practical approach; through physical killing as by trapping. Unfortunately, clearing more bushes, increases the favourable environments for multiplication of these birds. We urgently need a project to physically destroy the birds on a regional basis. This has been proposed.

Atadan

My feeling is that clearing land reduces the bird population, but your opinion contradicts this. Can you make this more clear?

Omolo

Bush clearing immediately surrounding crops is recommended to eliminate perching near the fields. However, wide areas, when cleared, provide a suitable habitat as the wild grasses would provide more food. These help to feed an increasing population even in the absence of crops.

Rai

My observations on the bristle-headed characteristic and bird resistance in Uganda are similar to those in Somalia. If both bristled and non-bristled varieties are grown together, the latter is preferred, but both are otherwise eaten as well. The disadvantage of the bristled ones is that the yields are low, making them a non-viable choice.

Okello

I saw a device in Kenya used for scaring birds from sorghum a few years ago. It was mounted on a tall mast. As its colour changes sharply at short intervals, birds were scared. I think this method could be copied by others.

Some advanced countries reduce bird populations by sterilizing them - by the use of certain pellets. I think this should also be considered as an alternative.

Taye

How practical is the proposed solar grain-cooling unit? Is it feasible for the small farmer, or even on the large scale? Are they now in use?

Odogola

The grainstore proposed would be suitable for large-scale storage such as traders, companies and cooperatives but not for the rural farmers as they store their grain unthreshed. It saves crops during periods of handling for export, or factory processing in large quantities. The small farmer benefits indirectly. They are not yet in use in Uganda.

Alahaydoian

What is the estimated cost of the solar cooling system?

Odogola

A simple flat-plate solar collector for use in a 10-ton-capacity brick-walled grain silo could be constructed of three 8-ft long galvanized corrugated iron sheets for the roof and two 8-ft plywood or papyrus mats, for the base, with an electric 1 Kw fan. The entire cost may be about US$ 300 to 350. Once in operation, it would run at USh. 8 per Kw-hr, an equivalent of $1.30 for 10 Kw-hr. Under current Uganda conditions, a pay-back of less than two years is predicted.

A REVIEW OF SORGHUM AND MILLET RESEARCH IN WESTERN KENYA DURING 1984

N.W. Ochanda*

Sorghum and Millets Research and Development in Kenya is served by a national program which was established in 1981. Its overall aim is to increase the production of these two crops whose decline has been caused by several factors, including low yields, high labor requirements for weeding and bird scaring, a high incidence of diseases and pests, including Striga, low prices and the lack of a good market for the predominantly brown sorghums grown.

The Lake Basin area of Kenya, which includes Nyanza and Western Provinces is the dominant growing area for sorghum and finger millet and represents the western component of the improvement program. All sorghum research in Kenya is co-ordinated from Western Agricultural Research station, Kakamega, which, along with its sub-centre at Alupe, is the main location for research activities on sorghum and finger millet in western Kenya.

In spite of the prolonged drought of 1984, which affected a large portion of the country and resulted in massive crop failure in some of the major food producing areas of Kenya, growing conditions in western Kenya were generally favourable allowing for both on-station and off-station research activities. Both the long-rains research program (March - June) and the short-rains program (September - December) went on as planned. The total rainfall recorded at Alupe Agricultural Research station in 1984 was 1,659 mm, while 1,620 mm were recorded at Kakamega.

Research activities on the two crops during the 1984 crop season involved experimental work in breeding agronomy and entomology. Most of this was on sites at the two stations. Linkage with extension services involved co-operation in on-farm research and participation in national extension activities which involved joint visits to farmers' fields and monthly discussion sessions.

The major research activities carried out at each of the two stations can be summarized as follows:

---

*Alupe Agricultural Research Station, P.O.Box 278, Busia, Kenya

A. Alupe Agricultural Research Station

1. Crop improvement

In 1984 a total of two sorghum trials and two nurseries were received from the Regional SAFGRAD Co-ordinator and grown out during the long rains at Alupe. In addition to these, other nurseries planted during this season included a seed rejuvenation and maintenance cum-Striga nursery, a hybrid nursery, and a seed increase nursery. In the short rains, an evaluation nursery of some elite lines selected from Katumani and a sorghum experimental hybrid nursery were planted.

2. Agronomy

- Bean-sorghum intercropping trial;
- Striga infestation in sorghum relative to cultivar and nitrogen trial;
- Striga trap crop trial;
- National extension program activities.

3. Entomology

- Sorghum shootfly insecticide screening trial, 1984 SR;
- Sorghum midge insecticide screening trial, 1984 SR;
- Sorghum variety screening trial, 1984 SR.

B. Western Agricultural Research Station, Kakamega

1. Crop improvement

- Finger millet regional varietal trial;
- Sorghum pedigree nursery.

2. Agronomy

- Finger millet fertilizer response trial;
- Finger millet weed control trial;
- Finger millet plant spacing/population trial;
- Time of planting/transplanting trial;
- Beans - finger millet intercropping trial.

REVIEW OF THE RESEARCH ACTIVITIES

Eastern Africa Co-operative Sorghum Regional Trials

This was one of the sets of trials received from the SAFGRAD Regional Coordinator. It consisted of 15 varieties plus one local variety (Sabina). The planting date was 4 April 1984 and the materials were set out in a randomized complete block design with four row plots replicated three times. Each row was 5 m long and the rows were spaced 75 cm apart. Seedlings were thinned to 15 cm intra-row spacing.

The mean data for grain yield, days to 50% flowering and height of the test material are given in Table 1.

Analysis of variance was carried out to determine differences among grain-yield means, of which turned out not to besignificant. The relative variation of yield was high (CV = 36%). The best performing varieties on a ranked basis were Tegemeo, 2KX 17/6, Serena, 76T1-23 and IS 8595. 5DX 160 and Makamash 79 were the only varieties which had yields below 2 tons per hectare.

On agronomic desirablility score, the best varieties were Tegemeo, Sepon 80-1, Serena, Seredo, and 2KX 17/6. Selection for advancement will take into account the varieties with superior yields and good general expression.

Pedigree nursery

A sorghum breeding nursery made up of F_2, F_3, and F_4 materials from the Ethiopian Sorghum Improvement Program was grown out at Alupe during the 1984 long rains. The planting plan and other information relating to the nursery is given in Table 2.

The total number of crosses in the three generations was 1,682. No scores were made on diseases but at maturity a visual appraisal was done for the different populations and single plant selections were made in the F_2 and F_3 materials. A total of 649 crosses represented by single-plant selections were advanced from the F_2s, and 210 crosses were advanced from the F_3s. From the F_4s, entire families were appraised and 18 were selected for advancement into a preliminary yield trial. The advanced generations were planted during the short rains of 1984 but plant growth was affected by high Striga incidence. The material has been planted again during the current season.

Table 1. Eastern Africa Co-operative sorghum Regional Yield Trial, grain yield, height and days to flowering of sorghum varieties planted at Alupe Agricultural Research Station in 1984 LR

Entry	Yield (tons/ha)	Plant height (cm)	Days to 50% flowering
Tajarib	3.69	172	66
Sepon 80-1	3.71	190	70
5DX 160	1.43	190	74
Serena	4.49	172	67
Seredo	3.08	173	68
E 525 Ht Red	2.99	193	71
2KX 17/B/1	2.31	193	72
Tegemeo	5.30	165	70
2KX 17/6	4.50	215	68
Gambella 1107	2.50	203	68
Melkamash 79	1.69	210	72
Badege	2.42	195	72
Urumimbi	2.15	175	72
76 T1-23	4.23	165	67
IS 8595	4.15	247	72
Sabina (local)	2.20	184	68
Mean	3.18	190	70
C.V%	36	11.3	9.3

Table 2. Planting plan for breeding nursery introduced from Ethiopia

Generation	Plot number	No of entries	Rows Number	Rows Length(m)	Rows Width(m)
F_2	1 to 255	255	4	10	0.75
F_2	298 to 394	97	4	10	0.75
F_3	395 to 1186	792	2	5	0.75
F_4	1614 to 2151	538	2	5	0.75

Crossing block for making hybrids

The FAO/Kenya Government Sorghum Improvement Program had evaluated over 200 pairs of A and B lines. Based on the information available on their maturity and adaptation, 6 A lines were selected and included in a crossing block to make hybrids by crossing with 9 restorer lines. The A lines and R lines used were:

A Lines	R Lines	
1. CK 60A	1. 2 KX 17	7.E525 Ht Reduction
2. Kafinum A	2. Lulu D	8. IS 76
3. 87/2DMS A	3. NES 830	9. SB 65
4. 8MSC 18 (W) A	4. Seredo	
5. 2219A	5. E35-1	
6. IS 104A	6. NES 7360	

Up to 80% seed set was achieved per panicle for all the crosses. The hybrids were planted for evaluation during the 1984 short rains but they need to be re-evaluated.

Seed rejuvenation and maintenance cum-Striga nursery

A fairly large amount of sorghum germplasm which had been accumulated at Alupe Research Station during the tenure of the FAO/Kenya Government Sorghum Improvement Program fell into disuse and suffered from improper storage after the project came to an abrupt end in 1981. These included local and exotic varieties, A and B lines, hybrids, and R lines. Apart from the fact that the germplasm needed rejuvenation, the specific reaction of most of this material to Striga infestation was not known. The seed rejuvenation cum-Striga observation nursery was planted on a Striga-sick plot at Alupe during the 1984 long rains. It consisted of an unreplicated nursery of the entire sorghum seed stock which was being kept at the staion. The test entries were grown in two row plots and Striga observed in between the two rows.

Most of the test entries suffered from high Striga infestation and expressed themselves poorly. Several Machakos/Yatta landraces stood out as performing reasonably well under such heavy infestation. These included MY134, MY 183 and MY 95-2. These results indicate the potential of local sorghum cultivars in future breeding for resistance.

Lowland yield evaluation and adaptation nursery

This nursery represented a part of a group of materials which the SAFGRAD Coordinator had evaluated and advanced into yield trials at Katumani in eastern Kenya and which had on visual evaluation been rated as agronomically elite. The nursery was planted at Alupe during the 1984 short rains in unreplicated two-row plots 5 m length. Eleven varieties from this group received high overall desirability scores at Alupe and were advanced into an on-going preliminary yield trial.

West Africa Regional Sorghum Trial

This material was received from Dr. Ramaiah through the E.A. Regional SAFGRAD Co-ordinator and was planted at Alupe during the 1984 short rains. It was planted in 4 m row plots in a randomized complete block design replicated four times. In agronomic desirability score, the best entries were 82-S-104, Framida, and S-35.

Other activities

Our elite varieties, including Seredo, Serena, MY146, E525, Dobbs Bora and Striga-susceptible checks such as NES 7360 and CK60B were also increased in large plots.

Bean-sorghum intercropping trial, 1984 LR and SR

Intercropping is a cropping system involving the planting of two or more crops on the same piece of land at the same time. In small-scale farming, which is common in most parts of Kenya, it is very popular, usually involving a cereal crop such as maize (main crop) with a legume crop such beans, cowpeas, or green gram.

The method of planting sorghum in Kenya is gradually changing from broadcasting to row planting. Farmers are also changing to short sorghum varieties which are also early maturing and high yielding as compared to the local varieties. These factors encourage intercropping of sorghum with other crops, maize and beans being the most popular. This was a preliminary trial aimed at assessing a number of factors in sorghum (Sorghum bicolor) and beans (Phaseolusvulgaris) that could be combined in an intercrop to achieve high yields with the minimum of management. Particular emphasis was given to plant population densities of the two crops.

Materials and methods

The experiment was conducted at Alupe Agricultural Research Station in the 1984 long and short rains. An early-maturing high-yielding sorghum variety, Seredo, was intercropped with big-seeded Rose-coco beans, also known for its fairly high yield. Four treatment combinations, consisting of two factors each at two levels, were studied in a randomized complete block design replicated four times in a 2^2 factorial. The sorghum plant population levels were 89,000 and 110,000 plants/ha and the population levels for the beans were 160,000 and 196,000 plants/ha. Sorghum and bean monocrop treatments, planted at the recommended plant populations for the region, were included. Between two rows of sorghum were alternate double rows of beans planted on the same day as the sorghum in 7.5 m x 6 m plots. Fifty kg DAP/ha was used in planting all sorghum plots, 100 kg DAP/ha on beans intercropped with sorghum and 150 kg DAP/ha on pure-stand beans. In the short rains these rates were raised by 50 kg each. This was necessary because the site chosen was poorer. Other management practices such as thinning, weeding and insect-pest control were done according to normal recommendations.

Required data were taken from the net plot which measured 32.5 m^2. The few selected variables which were analysed included grain yield and land equivalent ration (LER). The latter was calculated as:

$$LER = \frac{\text{Sorghum yield in mixture}}{\text{Sorghum yield in pure stand}} + \frac{\text{Bean yield in mixture}}{\text{Bean yield in pure stand}}$$

Results and discussion

The mean grain yields for beans and sorghum obtained for the different treatments are given in Tables 3 and 4. Sorghum yields of about 3 t/ha were obtained but the bean yields were quite low (Table 3). LER were greater than one for the treatment combinations, with that of the higher population of the two crops being slightly higher. Table 4 summarizes the grain yield for sorghum only as the two-month drought prevent the beans from flowering and seting seeds. For sorghum, treatment 2 (see Table 4) 3,266 kg/ha was also the highest overall 3,266 kg/ha followed by treatment 4, 2,877 kg/ha. The intercrops yielded relatively less sorghum, not only in comparison with the monocrops but also with their counterparts in the long rains. In the long rains the significantly lower yields for the two crops in the intercropped plots compared to the monoculture could be attributed to the competitive effect of the two crops.

In the short rains the sorghum in the intercropped plots showed an even greater reduction in yield, although the beans yielded nothing. This could also be due to competition for nutrients and moisture, although this does not tally well with even higher yields for the sorghum monocrop in the long rains. These results, however, are not conclusive as two more growing seasons will be planted with the same experiment before final conclusions can be drawn. LER greater than one could mean a yield advantage for intercropping. However, this also needs further verification.

Table 3. Mean grain yield (kg/ha) for intercropped beans and sorghum, 1984 long rains

Treatment no.	Sorghum plant population (plants/ha)	Bean plant population (plants/ha)	Yield (kg/ha)		
			Sorghum	Beans	LER
T1	89,000	160,000	2,951	262	
T2	89,000	-	3,156	-	1.67
T3	110,000	196,000	2,667	283	
T4	110,000	-	2,528	-	1.85
	200,000		-	357	
S.E			0.36	0.23	
C.V(%)			8.20	47.92	

Notes:
T1 = Sorghum spaced at 75 cm x 15 cm intercropped with beans spaced at 25 cm x 15 cm.
T2 = Pure stand sorghum spaced at 75 cm x 15 cm.
T3 = Sorghum spaced at 60 cm x 15 cm intercropped with beans spaced at 25 cm x 15 cm.
T4 = Pure-stand sorghum spaced at 60 cm x 15 cm.
T5 = Pure-stand beans spaced at 50 cm x 10 cm.
LER = Land Equivalent Ratio.

Table 4. Mean grain yield (kg/ha) for sorghum intercropped with beans, 1984 short rains

Treatment no.	Sorghum plant population (plants/ha)	Bean plant population (plants/ha)	Yield (kg/ha) Sorghum
T1	89,000	160,000	2,062
T2	89,000	-	3,266
T3	110,000	196,000	2,285
T4	110,000	-	2,877
	-	200,000	
S.E			0.8
C.V %			21.81

T1 = Sorghum spaced at 75 cm x 15 cm intercropped with beans spaced at 25 cm x 15 cm.
T2 = Pure-stand sorghum spaced at 75 cm x 15 cm.
T3 = Sorghum spaced at 60 cm x 15 cm intercropped with beans spaced at 25 cm x 15 cm.
T4 = Pure-stand sorghum spaced at 60 cm x 15 cm.
T5 = Pure-stand beans spaced at 50 cm x 15 cm.

National extension trial and visit (T and V) programs (NEP)

The NEP was introduced in Busia and Kisumu Districts at the beginning of 1985 with the aim of advancing the newly recommended technologies from research stations to the farmers by the fastest possible means. This called for closer liaison between the research officers and the extension staff under the leadership of the District Agricultural Officer and entailed not only extending farming knowledge through the contact farmers and their demonstration plots but also carrying out on-farm trials on all over the two districts.

In Busia District, one of the main target areas served by the Alupe Agricultural Research Station, sorghum was selected as one of the crops needing on-farm trials, together with maize and cotton. The problem areas were tentatively diagnosed to be methods of planting and population density in the Lake Basin Region's small-scale farming areas.

Sorghum population and method of planting, 1984 LR

Seredo sorghum, one of the recommended improved varieties, was planted in nine sites in the three administrative divisions (Amagoro, Nambale and Hakati) with planting sites being delineated according to agro-ecological zone, with one replication per site in the 1984 long rains. Compound fertilizer, 20:20:0, was applied at the time of planting at the recommended and affordable rate of 20 kg N and 20 kg P per ha. All sites were planted to a population density of 70,000 to 110,000 plants/ha at a spacing of 60 cm x 15 cm, 75 cm x 15 cm, 75 cm x 12 cm (all one plant per hole) and 60 cm x 30 cm, 75 cm x 30 cm and 75 cm x 24 cm two plants per hole). Apart from planting, which we did together with the farmers, all crop husbandry, weeding, thinning, bird scaring, etc., was carried out by the farmers themselves.

During the course of crop growth, all the farmers observed that managing plots with two plants per hole, especially weeding, was easier than plots with one plant per hole. However, we could not obtain results as some farmers ignored the various operations, while others harvested the plots before we could reach the sites. However, in the 1985 long rains we look forward to repeating these experiments with the addition of fertility and variety factors because the farmers expressed an interest in these areas.

Sorghum entomology

Sorghum shootfly insecticide screening trial

The objective was to screen insecticides which can control sorghum shootfly effectively in late planted sorghums. The experiment was in a randomized complete block design with four replications. The chemical treatments used were Dimethoate 40% E.C., Sumithion 50% M.L., Sumicidin 10% E.C., Ambush CY5% E.C., Thiodan 35% E.C., Furadan 5% granules and control. All the chemicals were applied at concentrations recommended by the manufacturers. Furadan granules were applied in furrows at planting, while all sprays were repeated three times: first spraying in the second week after germination, the second spraying in the fourth week after germination, and the third spraying in the sixth week after germination. The number of plants with deadhearts was recorded up to seven weeks after germination.

The mean number of plants with dead hearts for the various insecticide treatments is shown in Table 5. The percentage of plants damaged by shootfly was high in all treatments indicating that none was effective against shootfly. Furadan 5 G and Sumicidin had the least number of plants affected by shootfly while Ambush CY and Thiodan had the highest number of plants affected by shootfly.

Table 5. Percentage of plants with shootfly damage

Chemical	Mean
Dimethoate 40% E.C	76.2
Sumithion 50% M.L	86.0
Sumicidin 10% E.C	71.2
Ambush CY 5% E.C	94.8
Thiodan 35% E.C.	96.5
Furadan 5 G	65.8
Control	78.5
S.E.	11.35
C.V.	27.9%

Sorghum midge insecticide screening trial

The objective of the experiment was to evaluate insecticides for controlling sorghum midge. The materials and methods were all similar to the shootfy trial except that Diazinon 60% was used instead of Furadan granules. For all treatments, except the control, four sprays were carried out: the first at the beginning of flowering, the second at 50% flowering, the third at 100% flowering, and the fourth at grain-filling stage. Data on number of heads affected by midge were recorded during harvesting by counting the number of heads showing midge damage symptoms. The results for the midge insecticide screening trial are shown in Table 6. They show that there were significant differences between all treatments and the control. Ambush CY 5%, Dimethoate and Sumithion had the lowest percentage of midge damaged heads. Diazinon and Sumicidin had the highest percentage of midge-damaged heads compared to other chemicals.

Mid-duration group

Statistically significant differences among varieties were obtained for the Kisii site only. For Kakamega and Busia the differences among varieties were not significant. Kisii gave very high yields, and Kakamega and Busia gave very low yields due to rainfall patterns. Gulu E, KA-2 and SN-7 were the best entries.

Table 8. Grain yield (kg/ha) of the mid-duration group of finger millet varieties

Variety	Kakamega	Busia	Kisii	Mean
Bu-3	1,882 (8)	1,035 (11)	3,630 (7)	2,185 (9)
SN-7	1,998 (4)	1,493 (2)	4,270 (4)	2,587 (3)
Gulu-E	2,049 (3)	1,083 (10)	5,276 (1)	2,802 (2)
KA-1	2,851 (9)	1,000 (12)	3,853 (5)	2,235 (8)
Serere-1	1,785 (11)	1,111 (8)	4,526 (3)	2,474 (5)
KA-2	2,090 (1)	1,354 (5)	4,798 (2)	2,747 (2)
KA-4	2,088 (2)	1,451 (3)	337 (9)	2,303 (6)
P-221	1,992 (5)	1,590 (1)	3,842 (6)	2,475 (4)
BU-6	1,932 (7)	1,104 (9)	2,123 (12)	1,720 (11)
B-1 (a)	1,974 (6)	1,375 (4)	3,504 (4)	2,284 (7)
KA-5	1,822 (10)	1,313 (6)	3,003 (11)	2,046 (10)
Local	1,351 (12)	1,125 (7)	3,235 (10)	*
S.E	225	176	490	
C.V%	27.8	28.5	22.9	

* No mean because the checks were different.
Numbers in brackets are ranks.

THE CURRENT STATUS OF SORGHUM AND FINGER MILLET RESEARCH IN WESTERN KENYA

Several research programs on sorghum and finger millet are currently under way both at Kakamega and Alupe. These programs were planted at the onset of the long rains of 1985, between March amd April. The work covers breeding agronomy and entomology, as in previous years.

Some of the programs, especially in finger-millet agronomy, are repetitions and continuations of previous experiments aimed at consolidation of data for specific and well tested recommendations for farmers. The areas being covered include a fertilizer response trial, a plant population/spacing trial, and weed-control and inter-cropping trials. These trials are going on at Kakamega.

In sorghum, the work is on yield trials, breeding, disease, and *Striga* nurseries. The Eastern Africa Co-operative Sorghum Screening Nursery is the largest with 1,000 entries.

This season the sorghum entomology section is focusing on the three major pests of sorghum in the Lake Basin: midge, shootfly, and stem borers. The time-of-planting trial aims to investigate the seasonal fluctuations in shootfly population to determine the optimum planting date for sorghum in Busia; the sorghum-insecticide trials screen insecticides which can control midges and shootfly; and a screening trial of several sorghum varieties for resistance against sorghum midge, sorghum shootfly and stalk borers is also under way.

The on-going sorghum agronomy work at Alupe is on *Striga*, sorghum/cowpea intercropping, and on-farm trials. On-farm research was initiated in the 1985 long rains after an informal survey of farmers within Chakol Sub-Location by a team of research and extension personnel. The survey established finger millet and sorghum as the dominant crops within the sublocation but that yields of the two crops were low due to use of inferior varieties and infertile soils.

Three improved varieties of sorghum (Seredo, Serena and E525), and three improved finger-millet varieties (Serere-1, P-283 and P-224), plus local checks of both crops, were planted in experiments on 14 farmer sites within the sub-location.

REPORT OF THE SORGHUM AND MILLET IMPROVEMENT PROGRAM FOR EASTERN KENYA, 1984

L.R. M'Ragwa and B.M. Kanyenji*

The Sorghum and Millet Improvement Program based at the National Dryland Farming Research Station (NDFRS, Katumani) caters for the dryland areas of Kenya which receive low rainfall (250-650 mm. per annum). The program aims at providing these marginal zones with improved practices and varieties of these crops and therefore helping the population in these areas to provide for at least part of their food requirement for themselves.

The 1984 short rains-season was a success in that we had enough rainfall during the growing period after three consecutive seasons without rain. Here we report only on a SAFGRAD millet trial and a weed-control trial in sorghum.

SAFGRAD Regional Pearl Millet Trial, 1984 SR

The objective of this trial was to identify superior genotypes for direct use in the national program. Eleven entries consisting of nine entries from other OAU states and three entries from Kenya were sown at Kampi ya Mawe (1,125m) in 1984 SR. The trial design a randomized complete block with four replications. The plot sizes were four rows x 5 m x 6 cm. The two middle rows were used for all data recording. NPK (20:20:0) fertilizer was applied during planting at 50kg/ha.

Results and Discussions

The maximum plant height for the trial was from the variety Ex-Bornu (240 cm) and the minimum was from variety Serere 6A (174 cm). The trial mean plant height was 233 cm and the coefficient of variation for plant height was 12.3%. In general, all the varieties were very tall: that is, they were over 150 cm.

---

* Millet and Sorghum Breeder, respectively, National Dryland Farming Research Station, Katumani, P.O. Box 340, Machakos, Kenya

Plant stand was not optimal because some entries in some replications lodged before harvest and made harvesting all the ears difficult. As a result, grain yield was estimated as a product of the number of plants harvested per plot and head weight. Table 1 shows that the highest yield per plant was from the entry Senegal-1 with 31.4 g/plant, and the lowest yielding was A/C MS-2 with 11.6 g/plant. The trial mean yield per plant was 17 g. The results showed that varietal differences were significant. The coefficient of variation for grain yield was 27.9%. Four varieties with superior field performance and with grain yields above the grain yields of the local check SC2 were selected for direct use in the national program. These are Senegal-1, Botswana-1, IKM 8021, and CIVT (Table 1).

Table 1. Performance of SAFGRAD Pearl Millet Regional Trial Planted at Kampi ya Mawe in 1984 SR

Entry	Plant height (cm).	Grain yield (g/plant)
SC_2	191	16.8
Serere 6A	174	14.0
Ankontes	205	16.0
A/C MS-2	225	12.0
Senegal-1	202	31.0
P80415	236	17.0
IKMU 8021	238	17.0
Ex-Bornu	240	12.0
Composite	235	16.0
Botswana-1	195	17.0
CIVT	216	18.0
Mean	233	17.0
C.V.%	12.3	27.9
LSD 5%	38.12	6.85

The Influence of smother cropping on weed growth and subsequent effect on yield

The use of smother crops is a cultural method of weed control. Smother crops compete with weed species for light, nutrients and moisture. However, they also compete with and possibly reduce the yield of the main crop. Thus, it is necessary to balance the reduction in the economic return from the main crop against the economic value and the weed-control value of the smother crop.

The objective of this study was to determine if the inclusion of a smother crop could replace weeding without a significant reduction in the yield of grain sorghum.

The experimental sites were Katumani and Kampi ya Mawe. Rainfall amounts during the season were 414 mm and 547 mm, respectively. The different treatment combinations used are as shown in Tables 2 and 3. The different crops used in the trial were 76 T1-23 sorghum, K80 cowpea, and KUR 26 green gram. A single row of the smother crop was planted in between two sorghum rows equidistant from each row, at intra-row spacings of 20 cm and 10 cm for cowpea and green grams, respectively. The sorghum spacings were 75 cm x 15 cm.

Results and discussion

Sorghum, like maize, requires at least two weedings during the growing season, and it is even more sensitive than maize to weed competition during the early stages of growth.

Results of sorghum yields, yields of smother crops, and weed dry-matter weights for the various treatments at Katumani are presented in Table 2. The inclusion of cowpeas supplemented with one weeding suppressed weed growth significantly more than in sole sorghum with one and two weedings. The yield of sole sorghum with two weedings was significantly higher than that of the sorghum/cowpea combination with one weeding. The inclusion of green grams supplemented by one weeding suppressed weed growth significantly more than sole sorghum with one weeding. The degree of weed growth suppression obtained in the sorghum/green gram combination with one weeding was equal to that obtained by two weedings in sole sorghum, but sole sorghum with two weedings yielded significantly higher than the sorghum/green gram combination with one weeding. Thus, the inclusion of the two smother crops effectively eliminated one weeding but caused a significant reduction in the yield of grain sorghum.

Table 2. Yield of sorghum and smother crops and weed dry matter weights at Katumani

Treatments	Grain yields (kg/ha) Sorghums	Smother crop	Weed dry matter at sorghum harvest (g/m^2)
S + 0 w	82	-	252
S + 1 w	2,309	-	147
S + 2 w	3,017	-	103
S + CP + 0 w	20	-	266
S + CP + 1 w	1,846	667	35
S + CP + 2 w	1,785	668	40
S + GGM + 0 w	13	11	123
S + GGM + 1 w	1,883	201	103
S + GGM + 2 w	1,761	185	96
LSD 0.05	528		24

S = Sorghum
CP = Cowpea
GGM = Green gram
w = Weeding

Table 3. Yields of sorghum and smother crops, and weed fresh weights at Kampi-ya-Mawe

Treatments	Grain yields (kg/ha) Sorghum	Smother crop	Weed fresh weight at sorghum harvest (g/m^2)
S + 0 w	165	-	1,058
S + 1 w	2,572	-	730
S + 2 w	2,971	-	397
S + CP + 0 w	596	1	717
S + CP + 1 w	2,378	64	577
S + CP + 2 w	2,128	631	90
S + GGM + 0 w	437	18	903
S + GGM + 1 w	24	101	602
S + GGM + 2 w	255	363	300
LSD 0.05	712		268

S = Sorghum
CP = Cowpea
GGM = Green gram
w = Weeding

Table 3 shows sorghum yields, yields of the smother crop and weed fresh weight for the various treatments at Kampi ya Mawe. There was no significant difference between weed-growth suppression obtained by the sorghum/cowpea combination supplemented by one weeding and that obtained by two weedings in sole sorghum. Thus, the inclusion of cowpeas effectively eliminated one weeding. The inclusion of cowpeas did not significantly reduce the yield of grain sorghum. There was no significant difference between suppression in weed growth obtained by the inclusion of green grams supplemented by one weeding and that obtained by weeding twice in sole sorghum, thus the inclusion of green grams effectively eliminated one weeding. The inclusion of green grams did not cause a significant reduction in the yield of grain sorghum.

Significant reductions in sorghum yield obtained at Katumani and non-significant ones obtained at Kampi ya Mawe by the inclusion of smother crops can only be attributed to competition between sorghum and the smother crop for available resources and not to weed density.

Gross field returns for the various production practices were calculated. Results obtained from the various practices are presented in Table 4. At Katumani, the highest gross returns were obtained from sole sorghum with two weedings. At Kampi ya Mawe, the highest gross returns were obtained from the sorghum/green gram combination with two weedings.

Table 4. Gross returns for the various production practices for Katumani and Kampi ya Mawe

	Gross return (KSh/ha)	
Treatments	Katumani	Kampi-ya-Mawe
S + 0 w	113	227
S + 1 w	3,175	3,537
S + 2 w	4,148	4,085
S + CP + 0 w	44	840
S + CP + 1 w	3,872	4,550
S + CP + 2 w	3,790	4,601
S + GGM + 0 w	64	677
S + GGM + 1 w	3,438	3,726
S + GGM + 2 w	3,202	5,039

S = Sorghum
CP = Cowpea
GGM = Green gram
w = Weeding

SORGHUM FOOD QUALITY AND UTILIZATION IN KENYA

R. M'Ragwa, F. Pinto, J. Bunge, N. Ochanda, and E. Mativo*

Sorghum (Sorghum bicolor (L.) Moench) is one of the staple foods in Nyanza, Western, and Eastern Provinces and many semi-arid areas of Kenya. However, planting has declined from 210,000 ha in 1981 to 170,000 ha in 1983 (FAO, 1984). Several factors such as grain damage by birds, people refusing to grow the crop due to its relatively inferior food quality, low guaranteed farm-gate prices, and lack of markets and industrial outlets for surplus grain, could be the causes of the decline (Pinto, 1982). Additional causes could be mainly psychological and most Kenyans prefer eating maize to sorghum products.

Sorghum research work which began in 1979 at the National Dryland Farming Research Station (NDERS), Katumani, was directed to finding agronomically desirable and good-food-quality varieties. Several workers have evaluated the processing and food-quality traits of sorghum varieties (Rooney and Murty, 1982). Food quality grains should be plump, pale yellow or white with a non-pigmented pericarp, no tannins in the testa and over 50% corneousness. When dehulled, the yield should be over 75% and the boiled pearled sorghum should cook, look and taste similar to rice. The hammer-milled flour should be coarse like maize meal, with a low fat content and should prepare acceptable ugali and uji. When milled in proper mills, it should produce a fine flour of high standard with particle size-distribution comparable to wheat flour, should be able to make acceptable composite flour and should prepare acceptable unleavened bread (chapatis) and leavened bread mkate (Pinto, 1982).

---

* Agricultural officer, Katumani Dryland Farming Research Station;
Former Team Leader, KEN78/016, Katumani;
Lecturer in Home Economics Department, Egerton College; Njoro, Kenya;
Agricultural Officer, Alupe Research Station;
Nutritionist, Eastern Province Hospital, Machakos, Kenya, respectively.

Rooney and Murty (1982) reported that most sorghum produced for food is used as unleavened bread (chapati), leavened bread (injera, mkate), thick porridge (ugali), thin porridge (uji), steam cooked and boiled products, snack food, and alcoholic or non-alcoholic beverages (busaa, marwa or fermented uji). The exact preparation techniques and the names of the products vary from place to place. The actual preparation technique did not affect the food quality of most products except that of porridge. They observed that the variety E-35-1 made desirable uji under acid and neutral conditions but unacceptable uji under alkali conditions. However, in Kenya, porridge is normally prepared with water at nearly neutral pH so the consideration of acid or alkali affecting porridge quality was not important.

In this paper results on food quality of 20 selected sorghum varieties are summarized for the major food products consumed in Kenya.

Materials and methods

Between 1978 and 1980 over 1,000 exotic and 1,103 local sorghum accessions were evaluated for plant type, maturity, disease tolerance, grain yield and other agronomic characteristics. Fifteen selected varieties were sent for uji and ugali tests to E. Mativo (nutritionist) at Machakos Hospital. In September 1980 a set of 35 promising varieties (5 local and 30 exotic) was selected at Katumani and Alupe Research Station (Busia) in 1980 LR. This material was sent to both the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT-India) and Egerton College (Kenya) for grain and food-quality tests.

The materials sent to ICRISAT were evaluated according to the standard methods described by Rooney and Murty (1982). The ugali and uji quality of the materials sent to J. Bunge (Egerton College) were scored by a panel of trainees on a scale of 1-5 where 1 = very bad, 2 = bad, 3 = fair, 4 = good, 5 = very good. The evaluation done at Katumani by the local staff was on the basis of the products' visual appeal and acceptability on eating.

Results and discussion

Thick porridge (ugali)

The ugali character is critical for determining sorghum quality in Kenya. The results given in Table 1 show that the ugali with the best taste and texture was made from varieties E35-1, 954063, NES 7360, 76 TI-23, 9DX 5/41/1, 2KX 17/5, 2KX17/B/1 and local line MY-183. These results suggest that pale-yellow or white ugali made from varieties with non-pigmented pericarps and highly corneous endosperms was rated high. It was also found that ugali color, taste, texture and aroma were the main characteristics which were critical in determining the acceptability of sorghum ugali. However, color was of minor importance to the panel members from Western and Nyanza provinces. The results showed that ugali made from varieties with pigmented pericarps, tannin-containing testa, and floury endosperms, like MY-148, MY-178, Muvemba local, Makueni local, Serena and Seredo, was undesirable (Table 2). This suggested that promising brown local landraces had undesirable ugali quality. But although Serena and Seredo ugali was not good looking, many people consumed it.

In 1980/81 confirmatory acceptability tests carried out with production farmers in Machakos District, and the local staff members at Katumani, showed that ugali made from white varieties 76T1-23 and NES 7360 proved to be better than that from Serena, E525HR and Seredo (Table 2). Pinto (1982) also reported that sorghum flour particle size was important in determining ugali qualities. Preference tests done on ugali prepared from hammer-milled flour samples of the variety 2KX71/3 and separated into three size fractions showed that the products made from the coarse flour were preferred to that made from very fine flour.

Thin Porridge (uji)

In Kenya, uji is a very popular sorghum product. The results presented in Tables 1 and 2 showed that uji made from any pale yellow or white variety, except that from 2KX17/5 (Machakos Hospital) and 2KX76/325, was acceptable. It was observed that varieties with high gel-spreading consistency made the best uji Table 1 and 2). Table 2 shows that the best uji with desirable taste, aroma and high gel-spread consistency was made from varieties E35-1, 954063, NES7360, 76T1-23, SC-566-14, 2KX17, 2KX17/B/1, 2KX14/1, 9DX5/41/1, Muvemba local, Dobbs, Serena, MY-183 and Seredo. Normally a cream, smooth flowing product with characteristic sorghum aroma was preferred. It was also noted that uji made from varieties with tannin-containing testa and floury endosperms was consumed despite the bitter taste. This suggested that uji color and taste were not the major factors determining its acceptability, provided the product had a characteristic sorghum aroma.

Table 1. Quality paremeters for sorghum grain

Variety	Grain color	(1)	(2)	(3)	(4)	(5)
MY-148 local	Red-yellow	3	23	6.45	34	4.4
MY-178 local	Light brown	3	21	6.30	38	4.5
MY-183 local	White	2	29	8.46	35	2.0
Muvemba local	Light brown	3	31	10.16	35	4.2
SC-566.14	Red	2	30	9.81	29	3.2
110-1-1-1	Pink	3	23	6.21	36	3.7
E525 HT reduction	Red-brown	5	22	5.64	36	4.5
Seredo	Red brown	4	24	6.15	38	3.9
Red Serena	Brown	2	26	6.78	47	4.1
9DX5/41/1	White	3	23	5.85	38	1.4
954063	Pale yellow	2	36	10.50	31	2.4
Makueni local	White pink	5	21	5.11	45	3.2
E35-1	Pale yellow	5	34	16.73	23	1.2
2KX76/325	White	2	25	6.53	35	3.2
2KX 17/5	White	2	26	8.25	33	2.6

Table 1. (Contd.)

Variety	Grain color	(1)	(2)	(3)	(4)	(5)
2KX 17/B/1	Pale yellow	2	24	7.96	34	2.4
2KX 17	White	2	28	9.05	34	1.9
76T1-23	Pale yellow	2	30	8.72	34	2.1
NES 7360	Pale Yellow	2	28	8.26	29	2.3
Lulu D	White	3	23	6.19	32	1.6

(1) Corneousness ranging from 1 (corneous) to 5 (floury).
(2) 1000 grain weight in grams.
(3) Breaking strength in kg.
(4) Water absorption of grain, %
(5) Flour color ranging from 1 (white) to 5 (brown).

Boiled sorghum, bread sorghum and puffing sorghum

Cooking tests done at Katumani during 1980 and 1981 showed that pearled sorghum of the varieties E35-1, NES7360, 76T1-23, and 2KX17 cooked, looked and tasted similar to rice. These varieties are over 60% corneous and when decorticated by using a PRL/RIIC dehuller, produced over 75% pearled sorghum products (M'Ragwa, unpublished data).

Fifteen per cent fine-particle-size sorghum flour from white varieties, or 10% maize or 10% cassava flour, could be blended with standard wheat flour to make acceptable leavened bread (mkate) (Crabtree, 1981). Routine tests on the brown varieties with floury endosperms (Table 1) made unsatisfactory flour for unleavened bread (chapati) preparation due to the presence of large quantities of fine brown pericarp fragments in the flour. Tests done to find out the varieties with good puffing qualities showed that good quality varieties were in the 2KX series (Pinto, 1982).

Table 2. Overall taste evaluation of sorghum foods

Variety	Ugali	Uji	Boiled sorghum
MY-148 local	Poor	Good	Fair
MY-178 local	Poor	Fair	Fair
MY-183 local	Good	Fair	Fairly good
Muvemba local	Fairly good	Fairly good	Fair
SC-566-14	Fairly good	Good	Fair
110-1-1-1	Poor	Good	Fair
Seredo	Fair	Fair	Fair
Serena	Fair	Fair	Fairly good
9DX5/41/1	Good	Very good	Fair
954063	Fairly good	Good	Good
Makueni local	Poor	Good	Fair
E35-1	Very good	Very good	Very good
2KX76/325	Fair	Fair	Good
2KX17/5	Good	Fair	Good
2KX17/B/1	Good	Fair	Good

.../contd.

Table 2. (Contd.)

Variety	Ugali	Uji	Boiled sorghum
2KX 17	Poor	Fair	Fairly good
76T1-23	Good	Very good	Very good
LULU D	Fair	Good	Fair
E525 HT Reduction	Poor	Good	Fair
Dobbs Bora	Fairly good	Very good	
2KX14/1	Fair	Good	

ACKNOWLEDGEMENTS

The authors are indebted to the following:

The GOK/FAO/UNDP for supporting this study; Dr. D.S. Murty (ICRISAT) and Mr. J. Kapasi-Kakama (Kenya Industrial Research and Development Institute) for assistance with food-quality tests; the Director of Katumani, for support; Dr. A Shakoor for providing constructive criticism on this manuscript; and the Director of Research (Kenya) for granting permission to publish.

REFERENCES

Crabtree, J. 1981. Composite flour baking technology, Kenya, UNIDO Consultant Report (KEN74/007).

FAO. 1984. Production Year Book, FAO, Rome.

Pinto, F. 1982. Terminal Report on Kenya Sorghum and Millet Development Project (KEN 78/016).

Rooney, L.W. and Murty, D.S. 1982. Evaluation of sorghum food quality. Sorghum in the Eighties: Proceedings of the international Symposium on Sorghum, 2-7 November, 1981. ICRISAT Center Patancheru, A.P., India.

DEVELOPMENT AND IMPROVEMENT OF PEARL MILLET COMPOSITE: INTRA-POPULATION IMPROVEMENT IN KATUMANI PEARL MILLET

L.R. M'Ragwa*

High yields in pearl millet can be achieved by the development of composite varieties. The composite varieties have distinct advantages as they have greater convenience in seed production, they offer a greater and a more readily available gene pool for further improvement. They serve as potential base populations for evaluation of more productive and better combining inbred lines for a hybrid program, and farmers can save seed from the previous harvest to plant the following season.

In composite development, the selected materials are intermated for three or four generations to break up established linkage groups and generate new combinations before initiating systematic intra-population improvement (Allard, 1960; Eberhart, 1972). A schematic method for the development and improvement of composite varieties in Katumani pearl millet is outlined below. The results on performance, response to selection and realized heritabilities in KAT/PM-1 are also reported in this paper.

Materials and methods

The material used was KAY/PM-1 variety cycle zero (Co) from which 252 half sibs were selected. The methods used are those for creating pearl millet random mating populations and their improvement by recurrent selection procedures (adopted from the ICRISAT pearl millet breeding program).

Procedure for effective recombination

Generation 1
We constituted a pollinator bulk from the seed of selected entries by weighing an equal amount of seed of each entry and calling it bulk "Bo".

(a) We planted one or two rows of each entry alternately with rows of "Bo".
(b) We selected and bulked the seed from four to eight plants within each entry at harvest.
(a) We took an equal amount of seed from the selected bulk of each entry and mixed it to form the new "polinator" bulk "B1".

*Millet Breeder, National Dryland Farming Research Station, Katumani, P.O. Box 340, Machakos, Kenya.

Generation 2

(a) Continued as for the previous generation 1 (a).
(b) Selected and bulked the seed from four to eight plants (open pollinated half-sib heads).
(c) Made the "B2" pollinator bulk with an equal amount of seed from each half-sib entry bulk.

Generation 3

Continued as for the previous generation, using the "B2" as pollinator. The procedure is followed as long as necessary until the entries lose their identity. By comparing the appearance of the derived entry row with the rows of the pollinator bulk, one can check whether recombination is completed. If any derived entry row still exhibits individual characteristics, it has not yet undergone complete random mating, and another generation of random mating is needed. When mating appears to be complete and the entries appear uniform, an equal quantity of seed is taken from each derived row to make the composite "C_0" bulk.

Recurrent selection procedures intra-population improvement in KAT/PM-1 Composite "2" progeny selection system

Cycle 1 (C_1) Generation 1 (G_1)

(a) Grew 200 or more half-sibs of selected plants from Co bulk in head rows.
(b) Selected more than 80% good-looking progeny rows. Selfed 10 or more best plants in each selected progeny row.
(c) Harvested the best selfed plants from each progeny row.
(d) Retained the selfed heads from the best progeny rows S_1 heads.

Generation 2 (G_2)

(a) Grew the selected S_1 (heads) from generation 1 as progeny rows in replicated trial.
(b) Selected 75% good looking progeny rows and selfed more than 10 best plants in each progeny row.
(c) Harvested the best selfed plants. Harvested and threshed these plants separately.
(d) Retained the S_2 heads.

Generation 3 (G_3)

(a) Grew the S_2 families from the selected head from generation 2 in replicated yield trial, as appropriate.
(b) Selfed 10 or more plants per entry and harvested the best selfed plants.
(c) Applied 10% to 20% selection intensity to select entries for recombination, basing selection on yield and other agronomic characters. Some entries may be location-specific and others may perform uniformly well across environments.
(d) Selected a few (5 to 10) best progenies from each site or across locations so as to develop various experimental varieties.

Generation 4 (G_4)

(a) Recombined the selected 10% or 20% entries from generation 3(c) for producing the composite bulk "'C_1 (cycle one).
(b) Recombined the selected progenies 3(d) to develop various experimental varieties.
(c) These were then tested in various nurseries and trials which, if successful, may go into commercial production. It is advisable to retain seed of the original selections separately in case they need to be reconstituted at a future date. This completes the first cycle of selection.

Cycle 2 (C_2) Generation 1 (G_1)

Grew out seed from half-sibs from "C_1" bulk and repeated the generations as in the first cycle.

Results and discussion

The results on performance, selection differentials, response to selection, realized heritability and comparison of C_0 and C_1 are shown in Tables 1 and 2. The results in Table 1 indicate that good genetic variability in grain yield exists and continues to exist in all progenies tested and that selection differential levels were maintained in all generations up to "C_1" bulk. The results suggest that in the first cycle of recurrent selection, S_2 progeny selection is very efficient and still maintains a high level of genetic variability in the progenies.

High levels of realized heritabilities suggest the presence of a high level of genetic variability in those generations and it appears that selection for high grain yield after selfing could be beneficial (Table 1). Although future performance of the improved version of KAT/PM-1 cannot be precisely predicted, the results indicate that genetic advances for grain yield can be expected to be maintained in future cycles of recurrent selection. It has also been reported elsewhere (Ragwa, 1981) that this composite has an adequate level of genetic and phenotypic variability. This makes further selection in the composite possible.

Comparisons of C_0 and C_1 (Table 2) also indicate that percentage change in grain yield is high (56.0%), and C_1 realized-heritability is high, suggesting that future improvement might be possible; and this could also appear in the subsequent experimental varieties. However, comparisons for other agronomic traits indicate a very low percentage change. This might have occurred because selection for these traits was ignored.

Table 1. Performance data, selection differential(s), response to selection (R), and realized heritability for grain yield in KAT/PM-1

Cycle(C) and generation (G)	Mean yield of generation (q/ha)	Calculated mean of selected individual	Selection differntial (S)	Response to selection (R)	Realized heritability (h2)
C_0	16.00	19.0	3.00		
G_1	18.75	22.0	3.25	3.0	0.923
G_2	21.00	22.2	1.20	0.2	0.167
G_3	22.00	24.9	2.90	2.7	0.931
G_4	24.00	25.2	1.20	0.3	0.250
C_1	25.00	28.0	3.00	2.8	0.933

Table 2. Comparison of original C_0 (KAT/PM-1) with improved C_1 for three characters.

Cycle	Grain yield (q/ha)	% Change	Days to 50% Bloom	% Change	Plant height(cm)	%Change
C_0	16.0	-	53.3	-	199	-
C_1	25.0	56.0	52.0	2.4	203	2.0

ACKNOWLEDGEMENTS

I wish to thank the Director and millet staff at Katumani for support during this study, and all those who have contributed in other ways. My thanks to the Director of Research (Kenya) for allowing the publication of this paper.

REFERENCES

Allard R.W. 1960. Principles of Plant Breeding New York: J. Willey & Sons.

Eberhart, S.A. 1972. Techniques and methods for more efficient population improvement in sorghum. In N.P. Rao & L. House (eds.). Sorghum in the Seventies. New Delhi: Oxford & IBN Publishing Co.

M'Ragwa, L.R. 1981. Field document on millets improvement in Kenya. Katumani Research Station.

DISCUSSION OF ALL PAPERS ON KENYA

Brhane

How meaningful is it to measure yields of millets and sorghum in the field on the basis of a single plant or A selected five plants, as reported in your paper?

M'Ragwa

Plant stand was not optimum because some entries lodged or were damaged by birds. As a result, grain yield was estimated on the basis of the number of plants harvested per plot so as to have a standard to compare the entries. Otherwise, visual evaluation was also used during selection and promotion of entries.

Brhane

The designation IS 76 to 76 TI-23, as followed in Kenya, is confusing since IS 76 is already assigned to another sorghum in the IS numbering system. I therefore suggest that this sorghum line be given a designation different from IS 76 in Kenya.

M'Ragwa

Yes. It is a mistake, made as early as 1978. The initial materials were designated IS 76 TI No.23. We noted the mistake. But since Kenya farmers, seed companies and all the literature from 1978 has this designation, we were not able to give it any other name as it would confuse everyone using this variety. However, change has been initiated by using 76 TI No.23 in recent literature and seed exchange check lists.

Hussain

What could be the reason for not getting the data in all the five locations in your multilocational testing of finger millet? Are the materials handled by your own staff or do the extension agents help you in conducting your trials?

Ochanda

The trials at Kakamega, Busia and Kisii were on research station land and reliable data were collected. At the other two sites, management was not good and no reliable data could be obtained.

Saadan

Apart from the color of a variety of sorghums, what are the factors which make good ugali (hard porridge)? Is it flour-particle size or the proportion of water used for cooking?

M'Ragwa

Both factors are important. Coarse flour was found to be the best. Per cent water absorption was also important as it was observed that the best ugali was made with very low water absorption.

Kabiro

During your investigation on sorghum utilization (ugali, uji boiled grain, composite flour, etc.) what method or procedure did you use to evaluate the food quality of the varieties under test?

M'Ragwa

Ugali quality was tested by a panel of five Kenyans in ICRISAT and scored on a 1-5 scale where 1 was good and 5 was poor. The test score scales for the other qualities tested in other institutions are explained in the paper under "Materials and methods".

Okello

What do you mean by the term "seed rejuvenation"? If it means to increase seed by some means, is it then possible to do it by planting the seed in a Striga-sick plot?

Ochanda

The great majority of the sorghum germplasm accumulated at Alupe during the tenure of the FAO program was in disuse and not properly maintained. So we had two nurseries of the entire seed stock being held at Alupe planted in two sites - one in a Striga-sick plot to assess the reaction of the test entries against Striga infestation, and the other in a Striga-free area to rejuvenate and maintain the seed stock.

Koma-Alimu

Your report shows the potential for incorporation of sorghum into baked bread. I think the difficulty is not consumer acceptance but getting a commercial company to start incorporating it. The composite-flour bread, I presume, would be cheaper and if the taste is as good as wheat bread it should be accepted quickly. We have our Serena lager as experience; it is well accepted now, but at first no brewery would think of using local cereals except imported barley. Has any bakery really tried the composite flour and faced the problem of no market?

Kanyenji

Work on incorporating sorghum flour into the already established wheat-dominated foods is actually going on, especially in biscuit and bread making. What is happening is that some sorghum flour is being incorporated into the wheat flour and the product is released to the market at specially selected locations for ease of survey. A survey is carried out to check on any reaction from consumers. If no negative reaction is noted, a higher percentage of sorghum flour is incorporated and another survey conducted. This will continue until an agreeable composition is reached.

At present it is not possible to give figures as the work is still going on, but a report from the biscuit industry indicates that sorghum flour has been incorporated without affecting quality. Reports from the domestic industry show that up to 30% sorghum can be incorporated as long as the sorghum flour is white in color.

Muhwana

I noticed that you failed to obtain midge control when you used insecticides. This was because you used a wrong criterion for data recording. You should have used a score method which would give the degree of damage. You should also take yield to back up your data and try to use systemic insecticides other than contact ones.

Doggett

Arising out of Mr. Muhwana's comment, in Uganda midge is always present but is kept in check by predators/parasites. Estimates of yield loss are necessary to be sure that midge in Western Kenya is really an important crop pest. Pesticide sprays may kill the predators/parasistes.

Doggett

On transplanting finger millet, this practice would be worth following up. It is used a lot in South India. Although more difficult than broadcasting, weed control is much easier. People in western Kenya, who are accustomed to transplanting rice might adopt the practice quite quickly.

Mitawa

The author should take heed of indiscriminate use of LER as an index to evaluate the efficiency of intercropping systems. More meaningful indices such as net economic returns should be employed since these are more relevant to the farmers. LER has limited use. Because it is arrived at by calculations of fractions, there is a danger that at times the denominator could be O, as was the case in Mr. Ochanda's report. Using LER as an index to evaluate the efficiency of intercropping systems would have led to the conclusion that intercropping is not advantageous. But, in fact, even in the event that no grain yield was realized, the beneficial effects to the soil, pest reduction effect, and increased total dry matter that could be used as animal feed would but point to the importance of intercropping.

Omolo

Land Equivalent Ration (LER) gives the relative use or productivity of a unit area of land. If LER = 1.5 this means that to get the same productivity in a mixture as from a pure stand one may require 50% more land. In which case, by planting crops in a mixture, 50% of the land saved could easily be used to produce another crop. If land is rented, the farmer would obviously save the rent value. When the LER value is greater than one, mixing pays but when the value is less than one mixing does not pay.

SORGHUM IMPROVEMENT IN TANZANIA, 1984/85

H.M. Saadan*

The National Sorghum and Millet Improvement Project (NSMIP) had a short period of rejoicing when the International Sorghum and Millet/Collaborative Research Support Program (INTSORMIL/CRSP) supplied the program with a specialist in sorghum/millet improvement, Dr. John Mann. He was stationed at Ilonga, which is the main research station for cereals and grain legumes. A number of sorghum lines he introduced from Texas were planted at Ilonga and were found to be well adapted. Some of the materials were used directly in our program and included in the National Yield Trial. Unfortunately, the project contract between The Tanzania Agricultural Research Organization (TARO) and INTSORMIL was terminated, so that Dr. Mann was unable to continue to work with us. However, the national project appreciates his efforts on the program.

The main breeding activities are carried out at Ilonga and a substantial amount of preliminary evaluation is conducted at other research stations. The main objective of sorghum research is to develop sorghum varieties which have a grain quality suitable for <u>ugali</u>.

Weather conditions and crop production

In the central and western parts of Tanzania, where sorghum/millets are important food crops, the year was dry. In some places drought was so severe that farmers failed to harvest a crop, especially those planting late maturing local varieties.

Table 1 gives rainfall data for some experiment at stations in Tanzania. Hombolo and Lubaga which represent major sorghum production zones received low rainfall of 300 and 424 mm, respectively. Even the relatively high rainfall recorded at Ifakara, Tumbi, Mlingano and Ilonga was below average.

---

*National Sorghum/Millet Breeder,
Tanzania Agricultural Research Organisation, Ilonga,
P.O. Ilonga, Kilosa, Tanzania

Table 1. Rainfall (mm) for some of the experimental research stations in Tanzania

	Ilonga	Ifakara	Mlingano	Tumbi	Mwanhala	Lubaga	Bwanga	Hombolo
January*	171.4 (11)	309.9 (21)	19.7	127.3 (12)	225.0(12)	172.7 (14)	79.9 (7)	148.2(14)
February	108.1 (8)	251.5 (14)	Nil	265.1 (13)	151.4 (9)	113.2 (9)	96.5(11)	83.0(16)
March	100.1 (7)	439.2 (13)	53.3	140.6 (10)	83.6 (7)	43.0 (10)	45.3 (8)	69.1(8)
April	168.8 (17)	544.5 (26)	538.8	156.1 (16)	190.0 (8)	94.9 (9)	71.9(14)	-
May	96.2 (10)	75.6 (15)	104.8	0.6 (1)	-	-	13.6 (4)	-
June	11.1 (3)	46.7 (9)	131.8	Nil	-	-	7.3 (1)	-
July	65.6 (11)	8.8 (3)	61.5	Nil	-	-	Nil	-
August	42.0 (15)	2.5 (1)	7.0	1.5 (1)	-	-	23.4 (3)	-
September	8.7 (1)	0.3 (1)	-	Nil	-	-	6.9 (2)	-
October	4.6 (2)	8.9 (3)	-	44.4 (7)	-	-	109.0 (9)	-
November	0	30.8 (3)	-	73.9 (7)	-	-	29.6	-
December	104.2 (9)	187.4 (15)	-	146.3 (10)	-	-	121.0	-
Total	880.8 (84)	1,906.2 (124)	916.9	995.8 (87)	755.0(36)	423.8(42)	604.4(59)	300.3(38)

*June to December are figures for 1983 whereas January to May are for 1984. Number of days in parantheses.

Planting dates play a very important role in marginal-rainfall sorghum production areas. Early planting or planting with the onset of the rains ensures that the crop grows during the period of adequate moisture, although the rains come over a short period of time. This has an impact on maximizing yield potential of recommended released sorghum varieties. Many small farmers who attempt to adopt released commercial sorghum varieties do not attain maximum grain yield due to low plant population and poor land preparation techniques. They either clear the bushes, burn trash and other plants without tilling the land or clear bush and carry out shallow cultivation before planting. All these techniques enhance soil erosion resulting in poor soil-water infiltration and high run-off during the rainy season. Therefore, in order to maximize the yield potential of released varieties of sorghum/millet, proper plant spacing and deep cultivation is required to allow more infiltration and less run-off.

In the eastern and coastal regions, the rains extend over a long period creating suitable conditions for the photosensitive local sorghum varieties. They are normally planted in December or early January and harvested in July, but it is recommended that the improved varieties be planted in mid-February or early March so that the crop matures at the end of the rainy season.

Crop improvement

Strategies

Presently the NSMIP is working towards evaluating breeding methodology which would provide immediate solutions for small farmers. The traditional pedigree selection method is being used and population breeding has also been introduced. Two populations with genetic male sterility from the Texas A & M Sorghum Program have been established. These are TP15, which has wide genetic diversity, and TP24 which consists of food type materials. Hybridization is commonly used to develop experimental hybrids.

Strong links between the national program and international and regional institutions such as ICRISAT, SAFGRAD/ICRISAT, SADCC/ICRISAT, and Texas A and M University, have helped procure useful breeding materials and advisory services.

Germplasm collections

In order to have a strong breeding program, a large collection with wide genetic diversity is necessary. Since the NSMIP was established a substantial amount of local varieties of sorghum and millet have been collected. The program has about 400 local varieties of sorghum, 70 of pearl millet and 30 of finger millet. Most of the pearl millet varieties were collected in Singida and Musoma regions, while the finger millet collection was done in southern Tanzania including Mbeya and Sumbawanga Regions. All germplasm collections were planted at Ilonga for seed rejuvenation during the 1983/84 cropping season. In sorghum, among the parameters recorded were plant height, number of days to 50% flowering, plant and grain color, presence or absence of testa, pericarp thickness, and endosperm texture. Several local varieties of sorghum were crossed to high-yielding introductions.

Varietal development

Some variability have been generated by crossing agronomically elite introductions with local varieties. Intercrosses among the elite introductions were also made. A major emphasis is on improving kernel characteristics and yield potential of selected progenies. To date there are very few varieties of sorghum/millet which have been released as commercial varieties. However, some materials have been found to be promising.

Sandala is a short-maturing local sorghum variety. It has excellent grain quality, tan plant color and a height of 2 meters. Some selection is used to improve this local variety.

Segregating populations and nurseries

In principle all the early segregating generations (F_2 and F_3) were supposed to be grown and selected in areas of eventual intended use. Unfortunately, since transport is a major limiting factor, our early generation selections were confined to Ilonga and Hombolo.

Dr. John Mann introduced 6,794 lines, both hybrids and populations of sorghum, from Texas A and M to Tanzania. These materials contained a wide range of diversity. They were:

360	experimental hybrids
44	pericarp nursery selections
242	full sib selections from TP 24
155	TP 15 entries
400	NaOH entries
849	MS_3 entries
3,497	F_2s
955	F_3s
3,301	Genetic stocks

6,994	Total number of introductions

Selected materials from these Texas A & M introductions were supposed to be grown at three locations, namely Ilonga, Ukiriguru and Hombolo. Since some of the introductions showed symptoms of a virus disease which was suspected to be maize dwarf mosaic virus, the materials were all confined to and planted at Ilonga until the disease situation could be clarified.

A grain mold nursery, composed of 40 entries in two replications, was planted in three high-rainfall locations: Ilonga, Ifakara and Milingano. Table 2 shows that, although there have been slight differences in crop maturity, all the entries matured more or less at the same time giving them equal opportunity for mold infection. Field and laboratory scoring was essential because kernels of some entries had complete glume coverage. Most sorghum varieties have uncovered kernels and tend to have a high score in the fields as well as in the laboratory. The germination test establishes a relationship between intensity of mold infection and percentage seed germination. Table 2 shows that low germination for the nursery grown at Ifakara was due to the high mold infection in this high-rainfall location.

In a <u>Striga</u> observation nursery planted at Mwanhala, Lubaga, and Bwanga UDO, TLSC323, a Mwambala local variety, and 2K x 89 showed potential for tolerance to <u>Striga</u>.

Table 2. Days to 50% flowering, field score (1-5), laboratory score (1-5) and per cent germination for the grain-mold-resistance observation nurseries grown at Ilonga, Ifakara and Mlingano.

Entry	Ilonga				Ifakara				Mlingano	
	Days to 50% flg.	Field score	Lab. score	Germ. %	Days to 50% flg.	Field score	Lab. score	Germ. %	Days to 50% flg.	Field score
1. E 2803	72	1.5	2.5	87	72	2.0	3.5	27	73	2.5
2. E 2804	68	1.0	2.5	63	78	2.5	3.0	47	80	1.5
3. ET 35-1	73	1.5	2.5	84	73	2.5	4.0	17	80	2.5
4. 5MX 6/4B/2	69	1.0	3.0	74	63	2.0	3.5	47	80	1.5
5. 5MX 6/4B/3	68	1.0	2.0	87	75	1.0	3.0	52	81	1.5
6. 5MX 7/2/1	72	1.0	2.5	81	74	2.1	4.0	20	80	2.5
7. 5MX 9/4B/1	70	1.0	2.0	91	68	1.0	3.5	53	81	1.5
8. 2KX 17/6	69	1.0	2.5	80	64	1.0	3.5	31	77	1.5
9. 2KX 89	68	1.0	3.0	77	80	1.5	3.5	17	75	1.5
10.2KX 97	74	1.0	2.0	86	88	1.0	2.5	54	80	1.5
11.5DX 135/13/1/3/1	70	1.5	2.0	83	73	2.0	3.0	30	79	1.5
12.E 2805	68	1.0	2.5	77	73	1.5	3.0	63	80	1.5
13.E 2830	68	1.5	3.0	75	62	1.0	4.0	36	79	1.5
14.TSX 173/7/2/1/1	80	1.0	3.0	70	69	2.5	5.0	35	83	3.5
15.E 2831	68	1.0	2.5	79	82	1.0	3.0	59	81	1.5
16.E 2841	70	1.0	2.5	76	69	1.0	3.0	53	77	1.0
17.TSX 12B/4/1/3/1	68	1.0	2.0	81	66	2.5	4.5	39	78	1.0
18.TSX 183/2/1/2/2	79	1.0	2.0	82	76	4.0	5.0	43	80	2.0
19.TSX 184/1/1/3/1	80	1.5	3.5	64	74	3.5	5.0	16	79	2.0
20.TSX 39/3/3/1/1	79	1.0	2.5	72	69	2.0	4.0	54	81	2.5
21.TSX 142/7/3/4/4	77	2.0	3.0	78	75	2.5	4.5	29	77	2.0
22.M90899	79	1.0	4.0	59	76	4.0	5.0	47	81	2.0
23.TSX 39/3.1/2/2	79	1.0	3.0	81	78	2.5	4.5	34	80	3.5
24.TSX 56/11/3/2/1	76	1.0	3.0	70	72	3.0	4.5	54	79	2.5

Table 2.(Contd.)

	Ilonga				Ifakara				Mlingano	
	Days to 50% flg.	Field score	Lab. score	Germ. %	Days to 50% flg.	Field score	Lab. score	Germ. %	Days to 50% flg.	Field score
25. TSX 95/1/1/3/2	73	1.0	3.0	82	73	2.5	4.5	19	78	3.0
26. TSX 95/1/1/4/1	71	1.0	3.3	68	90	2.0	3.5	30	74	1.0
27. TSX 95/1/1/4/2	75	1.0	2.5	88	76	2.0	3.5	17	74	1.0
28. TSX 108/1/1/2/2	75	1.0	2.5	87	72	3.0	5.0	42	80	1.0
29. TSX 118/5/3/3/2	72	1.0	3.0	71	72	3.0	5.0	17	78	1.5
30. TSX 120/5/3/1/2	72	1.5	2.5	81	69	3.5	5.0	21	75	3.0
31. TSX 125/2/4/3/2	73	1.5	2.0	80	88	3.0	5.0	27	77	2.5
32. TSX 135/4/2/3/1	74	1.0	2.0	81	72	4.0	4.5	14	73	1.5
33. TSX 142/6/1/1/1	75	1.5	2.0	81	75	4.0	5.0	18	71	1.5
34. TSX 142/7/2/2/2	79	2.0	2.0	80	79	3.0	5.0	21	81	1.5
35. TSX 156/2/1/2/2	77	1.0	2.0	84	78	2.5	4.0	14	78	2.0
36. TSX 156/2/1/3/2	77	1.5	2.0	91	75	3.0	4.5	13	74	2.0
37. TSX 182/3/1/3/2	80	1.5	3.0	82	68	3.0	4.5	7	81	2.0
38. TSX 182/3/2/3/1	79	1.0	2.5	86	63	2.5	4.0	16	82	3.5
39. TSX 182/3/2/3/2	80	1.0	2.5	80	80	3.0	4.0	9	80	1.5
40. TSX 194/8/2/1/2	83	2.0	4.0	65	76	4.0	5.0	32	83	1.5
Mean	74	1.2	2.6	79					79	1.9
LSD	5								6.62	
CV,%	3.2								2.10	

Cooperative activities

International Tropical Adaption Trial (ITAT)

This nursery had 33 entries and was planted at Ukiriguru. Table 3 gives agronomic data for this trial. In terms of agronomic desirability, a number of entries looked good which shows that the materials are well adapted at Ukiriguru. Since many of these entries were hybrids, there is a need to explore more of the potential uses of hybrids in the Ukiriguru area. The NK 300 entries with 67% midge damage score were the most susceptible. Other entries which showed susceptibility were RTx7078, ATx 623 x RTx 7000, and ATx 623x Rio. Most of the entries showed some resistance to diseases and midge damage. Grain yields of most of the hybrids were reasonable and ATx 623 x CS 3541 gave the highest grain yield with 3296 kg/ha. Other high yielding hybrids included ATx 623 x 770S1, ATx 623 x 79T 269-5, ATx 623 x 77CS56 and ATx 625 x R 6956, ATx 625 x R 3388, A4Rx RTx 430, A7905 x 76Cs 478. From this observation it seems that ATx 623 combines very well to produce good hybrids. The lowest yields were recorded from RTx 7078 and NK 300 producing grain yields of 370 and 491 kg/ha, respectively. Most of the entries had uniform maturity and short plant height.

International Disease and Insect Nursery (IDIN)

This nursery had 30 entries and was planted at Ukiriguru. The results are shown in Table 4. The overall plant desirability scores showed that most of the entries were poor agronomically. The best three entries were R3338, Tx2536, and ATx623x Sc 326-6. As far as days to 50% flowering are concerned GPR 148, SC 748-5, SC 630-11E(11), and BT x 623 were among the early flowering entries. The latest was MB9-13-1-1-bk-bk-bk flowering 85 days after planting. In terms of insect infestation R 3224, Tx 2783, TX 2775, 77CS1, TAM 428 and VG 148 (801-27942) were resistant to shootfly attack. Entries which showed some tolerance to American bollworm included R 5388, 77CS1, BTx 625 and TX 2536. In terms of stem borer and sorghum midge infestation, there was generally low damage to plants which indicates some level of resistance. Although some entries showed good levels of tolerance to one or two of the three leaf diseases (grey leafspot, bacterial stripe, and leaf rust) no entry was resistant to all three.

Table 3. Agronomic data for the International Tropical Adaptation Trial grown at Ukiriguru

Entry	Grain yield (kg/ha)	1000 seed weight (g)	Mold score (1-5)	Desira-bility (1-5)	50% flg. days	Plant height (cm)	% midge damage
1. BTx 3197	1,370	3.0	1.0	1.3	72	105	13.3
2. BTx 378	1,454	2.9	1.0	2.0	72	101	11.7
3. BTx 623	1,472	2.6	1.0	1.6	71	121	7.3
4. BTx 625	1,667	2.6	1.0	1.6	65	99	8.8
5. RTx 7000	1,426	2.8	2.5	2.0	70	96	26.7
6. RTAM 428	1,343	2.5	1.3	1.3	66	94	9.0
7. RTx 430	1,981	3.0	1.5	2.0	71	87	28.3
8. RTx 7078	370	2.7	3.0	1.0	69	84	36.7
9. ATx 378x RTx 7000	1,574	3.0	1.6	1.6	68	98	16.7
10. RS 610	685	3.2	2.0	1.6	68	109	8.3
11. ATx 399x TRx 430	1,306	3.7	1.5	1.0	72	91	28.3
12. ATx 378 x RTx 430	1,203	3.4	2.0	2.0	70	104	16.7
13. ATx 623x RTx 430	1,046	3.0	2.3	1.3	73	109	15.0
14. ATx 623x RTx 7000	1,417	3.2	0	2.0	72	101	33.3
15. ATx 623x RTAM428	1,982	2.7	1.5	1.3	69	105	20.0
16. ATx623xSCO599-11E	1,769	2.3	2.0	1.0	72	111	10.7
17. ATx623xCS3541	1,296	2.9	1.6	1.3	67	144	11.3
18. A4RxRTx430	2,667	3.1	1.5	1.0	71	101	14.0
19. ATXx623x74CS5388	2,259	2.7	1.5	1.3	70	129	
20. ATx623x77CS256	2,926	2.1	3.0	1.0	67	118	4.0
21. ATx623xRTx431	2,343	2.1	1.0	1.6	67	130	5.7
22. ATx623xADN55	2,130	3.2	2.3	2.0	70	115	4.7
23. ATx625xSC0326-6	1,620	2.5	1.3	1.0	69	111	8.7
24. ATx623x79T269-5	2,944	2.0	2.0	1.3	73	119	4.7

Table 3. (Continued.)

Entry	Grain yield (kg/ha)	1000 seed weight (g)	Mold score (1-5)	Desira-bility (1-5)	50% flg. days	Plant height (cm)	% midge damage
25. ATx 625x76CS478	2,389	2.8	2.0	1.0	65	118	2.0
26. ATx625xR3388	2,731	2.5	2.0	1.3	71	114	7.3
27. ATx623x80Cs2241	1,685	2.7	2.3	2.0	70	103	8.0
28. ATx623x76CS490	2,555	2.6	1.0	1.3	69	123	4.0
29. ATx625xR6956	2,741	2.4	1.5	1.3	70	136	4.0
30. A7904x76CS490	2,444	2.8	1.0	1.6	69	106	9.0
31. ATx623X77CS1	3,056	3.1	2.6	1.6	70	133	4.0
32. ATx625XRTx430	1,760	2.6	2.3	1.3	63	110	8.3
33. A7905x76CS478	2,648	3.1	0	2.0	70	110	4.0
34. ATx623xRio	2,676	2.6	1.6	1.6	68	171	30.0
35. NK 300	491	2.2	2.0	3.0	69	107	66.7
36. NK 300 white	1,711	2.3	2.0	2.0	71	106	66.7
37. Local Serena	1,611	3.5	1.3	1.6	73	110	28.3
38. Local Lulu D	1,722	3.7	1.0	1.3	72	101	23.3
Mean	1,934	2.8	1.7	1.5	70	111.4	16.3
CV,%	25.5				5.7	6.4	

Table 4. Results of the International Disease and Insect Nursery grown at Ukiruguru.

Entry	A	B	C	D	E	F	G	H	I
1. B35-6	67	2.0	5.0	17.0	2.0	1.0	2.5	1.5	4.5
2. 77CS2(SC170-6)	67	2.0	12.0	3.0	5.0	2.0	2.0	1.0	3.0
3. SC 326-6	72	1.0	8.0	5.0	3.0	2.0	1.0	1.0	3.0
4. SC 414-12	66	1.0	8.0	6.0	7.0	3.0	2.0	2.5	3.0
5. SC 599-11E	71	4.0	5.0	9.0	4.0	1.0	3.0	2.0	3.5
6. SC 748-5	64	1.0	5.0	6.0	3.0	3.0	2.0	1.0	3.5
7. SC 630-11E(11)	65	1.0	10.0	12.0	3.0	3.5	2.5	2.0	4.5
8. IS 9530	72	4.0	2.0	3.0	3.0	2.0	1.0	3.0	3.5
9. R 3338	81	2.0	7.0	5.0	3.0	2.0	1.0	1.0	1.5
10. R 3224	65	0	12.0	3.0	3.0	2.0	1.0	1.0	2.5
11. TX 2783	67	0	12.0	4.0	4.0	2.0	1.0	2.0	2.0
12. GR2-14-1-bk-bk-bk	72	1.0	4.0	9.0	4.0	4.0	0	3.0	4.0
13. R 6956	72	2.0	8.0	4.0	4.0	2.5	2.0	3.0	3.0
14. TX 2775	73	0	11.0	4.0	4.0	2.0	2.5	2.0	2.0
15. BTx 2761	73	1.0	14.0	6.0	3.0	2.5	3.0	3.0	4.0
16. R 5388	72	2.0	7.0	14.0	0	3.0	2.0	1.0	4.0
17. 77CS1	71	0	8.0	4.0	0	2.5	0	0	4.0
18. QL3 (India)	70	1.0	8.0	7.0	2.0	4.0	2.5	2.0	4.0
19. BTx 625	68	1.0	9.0	3.0	0	3.0	0	0	3.0
20. BTx 623	65	3.0	6.0	12.0	3.0	3.0	2.0	2.0	3.0
21. GPR-148	63	1.0	8.0	8.0	8.0	0	0	3.0	4.0
22. CS 3541	71	2.0	8.0	5.0	4.0	1.5	0	2.0	3.0
23. TAM 428	73	0	11.0	3.0	4.0	2.5	1.5	2.0	2.0
24. TX 430	71	1.0	10.0	4.0	2.0	3.0	0	2.0	3.0

Table 4. (Continued)

Entry	A	B	C	D	E	F	G	H	I
25. TX 2536	67	4.0	10.0	6.0	0	2.0	0	1.5	1.5
26. TX 7078	73	3.0	6.0	13.0	1.0	2.0	1.0	2.5	4.5
27. BTx 378	72	2.0	10.0	10.0	7.0	3.0	3.5	2.0	3.5
28. MB9-13-1-1-bk-bk-bk	85	3.0	13.0	3.0	2.0	1.5	1.5	1.5	3.5
29. VG146(80L-27942)	76	0	7.0	5.0	8.0	1.0	0	2.0	3.0
30. ATx623 x SC326-6	71	2.0	8.0	7.0	2.0	2.0	2.0	2.0	1.5
Mean	71	2.0	8.0	7.0	4.0	2.4	1.0	2.0	3.3

A = 50% flowering days, B = Shootfly, C = Stem borer,
D = Sorghum midge, E = Grey leaf spot, G = Bacterial stripe,
H = Leaf rust, I = Overall desirability

Note
Disease and agronomic desirability scores on a scale of 1-5.
Insect scores represent mean number of plants damaged.

Eastern Africa Cooperative Sorghum Regional Trial (Low Elevation Set, Ilonga)

This trial was planted at Ilonga and was composed of 16 entries. Generally the crop performance was fair, although some entries had low plant populations. Table 5 shows the high yield potentials of Gambella 1107, Serena, E 525HT and the local check (Serena) producing grain yields of 5,444, 3,889, 3,833 and 3,833 kg/ha, respectively. The lowest yield was recorded from IS 8595 and Tajarib which produced 555 and 278 kg/ha, respectively. Almost all entries were less than 2 meters high, except Badege and Urumimbi which had heights of 253 and 245 cm respectively. The early maturing entries included IS 8595, 2KX 17/B/1, Tegemeo and Melkamash 79. The tall varieties were late maturing.

Eastern Africa Cooperative Sorghum Regional Trial (Very Dry Lowland Set, Hombolo)

The trial had 11 entries and was planted at Hombolo which is the driest off-station site in the sorghum program. Table 6 shows the yield potentials of some early maturing-sorghum varieties. The highest grain yield was recorded from Makueni, 3KX 76/5 and 76T1-23 producing 3,438, 3,078, and 3,011 kg/ha, respectively. Low plant density at harvest resulted in poor grain yield for Lugugu which is a local variety. Most of the varieties were early in maturity and short in height, except Lugugu which measured 274 cm and flowered in 97 days.

Eastern Africa Cooperative Regional Sorghum Trial (Intermediate Elevation Set)

This trial was planted at two locations, Ukiriguru and Tumbi. It consisted of nine entries of which most had poor stand establishment. As shown on Table 7, most entries had low yields due to poor stand establishment. At Ukiriguru, Bakomash 80 had the highest grain yield followed by Buraihi and ESIP 12, producing 1,711, 1,622 and 1,211 kg/ha, respectively. At Tumbi the best yielding entry, with 1,322 kg/ha, was Buraihi. Poor soils at Tumbi might have had an effect on grain yield. At both locations, SVR 157 was much taller than the other entries except at Ukiruguru where the local check attained the tallest height. The late flowering varieties at Tumbi were SVR 157 and SVR 8.

Table 5. Sorghum Regional Trial, low elevation set, Ilonga

Entry	Yield (kg/ha)	Plant height(cm)	Days to 50% flowering
1. Tajarib	278	169	78
2. Sepon 80-1	3,056	150	80
3. 5Dx 160	2,944	166	89
4. Serena	3,389	150	80
5. Seredo	1,944	149	81
6. E 525 HT	3,833	156	82
7. 2Kx 17/8/1	3,056	158	83
8. Tegemeo	2,111	157	84
9. 2Kx 17/6	2,944	138	89
10.Gambella 1107	5,444	176	80
11.Melkamash 79	2,722	161	83
12.Badege	1,500	253	93
13.Urumimbi	1,278	245	91
14.76 TI-23	1,056	141	80
15.IS 8595	555	185	82
16.Local (Serena)	3,833	159	79
Mean	2528	170	34
LSD	1690	22	5
CV,%	40.0	7.9	11

Table 6. Agronomic data for the Eastern Africa Cooperative Sorghum Regional Trial, very dry lowland set, Hombolo

Entry	Yield (kg/ha)	Plant height (cm)	Days to 50% flowering
1. Gharib red	2,378	196	44
2. Gharib white	2,823	193	44
3. 3K x 72/1	2,489	104	56
4. 3K x 71/1	2,500	122	63
5. 3K x 73/4	2,553	151	58
6. 3K x 73/5	3,078	141	56
7. 50 x 135/13/1/3/1	2,833	239	70
8. 76 TI-23	3,411	145	56
9. Makueni	3,483	199	67
10.DB 822	2,253	196	69
11.Local (Lugugu)	94	274	97
Mean	2,489	169	62
LSD	1,147	24.7	
CV, %	27	8.6	

Table 7. Agronomic data for the Eastern Cooperative Sorghum Regional Trial, Intermediate Elevation Set, grown at Ukiriguru and Tumbi

	Ukiriguru			Tumbi		
Entry	Yield (kg/ha)	Plant height (cm)	Days to 50% flg.	Yield kg/ha	Plant height, (cm)	Days to 50% flg.
1. Buraihi	1,622	162	70	1,322	118	77
2. SVR8	356	140	81	722	120	100
3. ESIP 12	1,211	137	76	850	120	83
4. Bakomash 80	1,711	135	77	444	119	83
5. SVR 157	111	216	99	800	204	112
6. Ikinyaruka	889	142	83	733	134	78
7. Susa	622	174	87	489	156	82
8. 2K x 17	600	104	76	155	85	98
9. Local check	555	240	102	933	112	80
Mean	353	161	83	717	130	88
LSD	386	22		950	20	11
CV, %	26	8		76	9	7

SAFGRAD Pearl Millet Regional Trial (Hombolo)

The trial had 11 entries in four replications planted at Hombolo. Table 8 shows the yield potential for the early maturing pearl millet varieties in the semi-arid areas of the country. Botswana 1, Serere Composite 17 (a released commercial variety), A/C MS2 and Serere Composite 2 produced the highest yields of 2,321, 1,913, 1,900 and 1,825 kg/ha, respectively. Poor stand establishment and low plant density resulted in Senegal 2 producing the lowest grain yield. The late maturing local variety (Buruma) did not form any grain due to lack of moisture at flowering.

ICRISAT Population Comparison Trial

This trial came from ICRISAT consisting of five populations and four cycles of selection. These populations were planted at Ilonga. The objective of the trial was to assess the progress made from recurrent selection in each population and to compare and select the best among the five ICRISAT populations for the Tanzanian situation. Table 9 shows that some of the entries had a good agronomic desirability score but many of them varied in plant height and grain color within each cycle of selection. Those populations which possess relatively poor agronomic eliteness produced very high grain yield and these included US/RC_3, TS/BC_4, and US/BC_2 giving grain yields of 4,889, 4,778 and 4,722 kg/ha, respectively. Some entries which had better agronomic eliteness produced less grain and among these were RS/RC_4, US/RC_4, RS/BC_5, and US/BC_3 producing grain yields of 3,278, 2,777, 2,666 and 2,361 kg/ha, respectively. However, RS/RC_2 which had the best agronomic desirability score of 1.0, gave a grain yield of only 2,389 kg/ha. In this trial it appeared that there was a general trend of improved agronomic eliteness as cycles of selections were advanced although this was associated with declining yield trends.

Future plans

<u>Varietal development</u>
The crossing program will continue in order to incorporate desirable traits and obtain varieties which would meet the needs of Tanzanian farmers. Breeding nurseries and progeny evaluations will continue to be done at Ilonga and Hombolo, with the possible addition of Ukiriguru, depending on transportation facilities.

Table 8. Agronomic data for the SAFGRAD Pearl Millet Regional Trial grown at Hombolo

Entry	Yield (kg/ha)	Plant height, (cm)	Days to 50% flg.
1. Ex-Bornu	1,504	172	47
2. Nigerian Composite	1,542	186	47
3. Serere Composite 2	1,825	184	36
4. A/C MS 2	1,900	179	43
5. Ankontes	1,117	157	46
6. CIVT	1,138	179	44
7. IKMU 8021	1,446	181	44
8. Senegal 2	467	165	35
9. Botswana 1	2,321	183	40
10. Serere 17	1,913	170	39
11. Buruma (Local)	Nil	214	70
Mean	1517	1791	45
LSD	626	22	16
CV,%	28	9	25

Table 9. Agronomic data for the ICRISAT Population Comparison Trial, Ilonga

Entry	Grain yield (kg/ha)	Plant height (cm)	Days to 50% flg.	Agronomic desirability(1-5)
1. US/R Original	2,056	169	78	3.0
2. US/R C_1	2,555	189	80	2.7
3. US/R C_3	4,889	172	79	2.3
4. US/R C_4	2,777	212	76	1.3
5. US/B Original	3,072	185	77	2.3
6. US/B C_2	4,722	166	80	2.3
7. US/B C_3	2,361	176	77	1.3
8. US/B C_4	2,722	177	76	2.0
9. RS/R Original	3,788	165	79	2.3
10. RS/R C_2	2,389	169	74	1.0
11. RS/R C_4	3,278	173	75	1.3
12. RS/R C_5	4,000	152	78	2.3
13. RS/B Original	3,611	164	79	2.3
14. RS/B C_2	3,500	189	78	2.7
15. RS/B C_4	4,778	151	79	2.7
16. RS/B C_5	2,626	122	73	1.3
17. WAE Original	2,389	185	79	2.0
18. WAE C_1	3,389	165	74	2.0
19. WAE C_2	3,944	192	79	2.7
20. CSH5	2,778	172	75	2.0
Mean	3233	165	79	2.1
LSD	903			
CV, %	51			

Seed increases

Seed increases of the promising entries from different nurseries such *Striga*, grain mold, shootfly and stem borer will be done at Ilonga.

Trials

A continuation of the previous years work. Some of the trials which will continue are:

(a) Progeny yield trial
(b) Grain-mold-resistance observation nursery
(c) Advanced yield trial
(d) *Striga*-resistance observation nursery
(e) Midge-resistance observation nursery
(f) Stem-borer observation nursery
(g) Tanzania sorghum variety trial
(h) Fungicide seed treatment to control smut
(i) Preliminary studies on pearling of sorghum.

Cooperative Activities

SAFGRAD/ICRISAT

More trials and breeding nurseries, contributed by the participating countries of eastern Africa, will be grown at different locations in Tanzania. We will continue our active participation in the Eastern African Regional Program.

SADCC/ICRISAT

The SADCC countries have jointly agreed to develop research activities on sorghum and millet in order to promote production of these crops in the region, and Tanzania will also continue to participate in this regional program.

SORGHUM IMPROVEMENT IN TANZANIA

D I S C U S S I O N

Taye

How does Tanzania feel about its participation in both the SAFGRAD/ICRISAT eastern Africa program and the SADCC/ICRISAT southern Africa program? Does this double participation create a burden on the national program?

Saadan

Since Tanzania has been actively involved in research activities with SAFGRAD, in exchange for materials and advisory services, we feel that we still need to continue cooperating with SAFGRAD/ICRISAT and SADCC/ICRISAT.

Mitawa

The situation would create only a temporary problem for our national program until such time that most of our staff come back from their post graduate studies. Then we would be able to assign people to take charge of the specific regional trials. Besides, it is my opinion that by participating in both SAFGRAD and SADCC regional programs, Tanzania might provide the opportunity for those in the SAFGRAD group to see materials from SADCC and vice versa.

Rowland

The LSDs in most of your tables seem very low. Are they perhaps in units different from those in the body of the tables?

Saadan

The tables were originally in quintals/ha and I inadvertently failed to convert the LSDs but I did convert everything else in the tables.

Iputo

In breeding for <u>Striga</u>-resistant varieties of sorghum and millets, is this an indication that other methods of control such as cultural, chemical, etc. have failed?

Saadan

Despite the presence of chemicals in the market for control of *Striga*, prices are so high that they are not economical and sometimes they are not available. Cultural methods are certainly practical but the problem is that differences do occur in farming methods which might cause difficulties in adopting cultural control. However, studies are being conducted on cultural methods of *Striga* control. To have a more economical and permanent solution to the *Striga* problem, plant breeders should utilize the genetic resistance which is available in the gene pool of sorghum cultivars. Resistance combined with high yield and good grain quality should give farmers better sorghum production returns in *Striga* infected areas.

Omolo

In Kenya, reports from Katumani indicated that sorghum planted with cowpea as a smother crop kept the population of weeds down. In Alupe, intercropping studies did not record anything on weeds. May I suggest that next time records on weeds be noted, particularly in the case of *Striga*. This would be the most practical method of controlling *Striga* by the subsistence farmers, particularly if *Striga*-resistant sorghums could be intercropped with cowpea.

THE POTENTIAL FOR SORGHUM AND MILLETS RESEARCH IN SOUTHERN SUDAN WITH EMPHASIS ON EASTERN EQUATORIA

Cirino Oketayot Oyiki*

Sorghum is the most widely grown and consumed crop in the whole of the Sudan (Abd Ellatif Nour, 1984). Millet, on the other hand, is mainly grown in western and southern Sudan.

Some successful sorghum research has been going on at Gezira Research Station, the National Research Headquarters, and other sub-stations. In most cases these research results were not directly related to the southern regions due to the differences in climate, soil, and farming patterns. Yambio Research Station, the main research station for southern Sudan, hardly functioned since its closure in 1958 due to the civil war.
Development agencies such as Norwegian Church Aid/Sudan Program (NCA/SP) also participated in agricultural activities on a zonal basis (Trygve Berg, 1984). Where some research activities remain they are broadly based, spreading their efforts over various crops and fields of research. This was partially due to the limited resources for the various research activities. The number of research personnel in the Southern Sudan is building up steadily. In 1982 the Regional Agricultural Research Technical Committee (RARTC) was formed in Juba. Since then research work in general started to gain momentum and several fruitful contacts were made between researchers in the Sudan and in neighboring countries, including SAFGRAD and ICRISAT.

Sorghum

Varietal screening has been the main component of sorghum research with limited emphasis on local varieties. Generally speaking, Ugandan varieties from Serere proved most successful in Equatoria Region. Serena is now widely grown for its earliness and yield. Soon Seredo will also be released to farmers. However, their poor storability and taste have been a drawback to more rapid acceptability. Farmers are willing to grow these sorghum varieties as a cash crop.

---

* Head of Agricultural Research Unit, NCA/SP, Torit, Sudan, P.O. Box 52802, Nairobi, Kenya

The potential of our local varieties, either through line selection or breeding programs, is unquestionable. A recent (1984) collection in one of the main sorghum-growing areas of southern Sudan, Lafon, contains the following numbers and races: 26 guinea-caudatum, 26 kafir-caudatum, 10 guinea, 8 guinea-kafir, 5 kafir, 1 dura and 1 bicolor. Stemler et al (1975) indicated that the caudatum race and its intermediate types are drought resistant.

Several forms of sorghum are recognized and grown with different names according to the various tribes in the regions. Wild types are common in the plains and rivers. Weed types frequently invade cultivated fields. In Lafon, Sakamoto indentified 19 varieties and ten sub-varieties. Among these varieties is Nyithin which is of the same type and similar to the famous Ethiopian variety Gambella 1107. Nyithin is one of the promising varieties in Eastern Equatoria. Lonyang is another outstanding variety commonly grown in Kapoeta. Both Nyithin and Lonyang have a lot of variation within themselves. Line selection of these two varieties is currently under way in Eastern Equatoria Province.

At their 1984 meeting RARTC presented the following resolutions as priorities:

- Screening of short-, medium-, and long-duration local varieties with emphasis on yield and the cropping calendar under the farming system perspectives;

- Study of the sorghum farming system as sole crop and under intercropping;

- Survey of economic importance of various pests and diseases, particularly with regard to birds, smut, molds, sorghum midge and Striga;

- Identification of ratoonable varieties and a study of the effectiveness of ratooning;

- Reduction of crop losses due to pests and diseases under smallholder farming conditions.

Finger Millet

Finger millet is grown in the southern regions for its earliness and resilience that enables it to mature during the hunger-gap period, May-June.

During the last RARTC meeting, various researchers reported that there was no significant difference in performance of selected local varieties which led to a proposal to discontinue or run-down finger-millet research. However, finger-millet research results from Uganda had been encouraging. Hilu and De Wet (1976) indicated that the center for diversity of finger millet is in Kenya and Uganda while ancestoral wild species are also distributed in the Sudan.

The 1984 RARTC resolution on finger millet encouraged further selection of high yielding local varieties in important finger millet areas. It also observed that there is a need to assess the potential of finger millet and establish optimum cultural technologies in intercropping systems.

Pearl millet

Brunken et al (1977) showed that wild proginators of pearl millet are distributed from Senegal to Central Sudan. The spread of these proginators to western and southern Sudan is a possibility. These are the areas where most pearl millet is grown in the Sudan but not much research has been done on it. The cultivated local varieties are tall, long maturing, and usually found intercropped with sorghum. Serere composite is the only exotic variety and it is already adopted in Eastern Equatoria for its early maturity. The local varieties, however, are more palatable.

RARTC 1984 resolved to assess the potentialities of pearl millet in a suitable intercropping pattern. Selection of high yielding local and exotic varieties in important pearl millet areas (Kapoeta and Pibor) was also stressed.

Present and future plans

- Execution of the 1984 Regional Agricultural Technical Committee resolutions on sorghum and millet;

- Further screening of exotic sorghum and millet varieties;

- Initiation of sorghum improvement program;

- Increased contact with researchers outsided the country, in particular SAFGRAD/ICRISAT;

- Collection and exchange of germplasm.

REFERENCES

Abd Ellalif Nour. 1984. The sorghum improvement program in the Sudan. In Proceedings of the Third Regional Workshop on Sorghum and Millet Improvement in Eastern Africa, Morogoro, Tanzania 5-8 June 1984.

Brunken J., De Wet, J.M. and Harlan, J.R. 1977. The morphology and domestication of pearl millet. Econ. Bot. 31: 163-174.

Hilu, K.W. and De Wet, J.M. 1976. Domestication of Eleusine coracana. Econ. Bot. 30: 199-208

Stemletr, A.B.L., Harlan, J.R. and De Wet, J.M. 1975. Caudatum sorghum and speakers of Chari Nile languages in Africa. Journal of African History 14: 161-183.

Trygve Berg. 1984. Sorghum in Eastern Equatoria Region of the Southern Sudan. In Proceedings of the Third Regional Workshop on Sorghum and Millet Improvement in Eastern Africa, Morogoro, Tanzania 5-8 June 1984.

SORGHUM AND MILLET IN SOUTHERN SUDAN

DISCUSSION

Koma-Alimu

Are steps being taken in the Sudan to find out the reasons for the exceptionally low yields of finger millet?

Oyiki

Most of the finger millet in Southern Sudan is grown in the sandy areas. However, there are severe variations in the soils. Inadequate rainfall is a major cause of low yields. Bird depradation in finger millet is not as serious as drought. No systematic soil survey of Southern Sudan has been carried out.

Brhane

Is there co-ordination between agricultural research in Southern Sudan and that in Wad Medani and other stations in the Sudan?

Oyiki

Theoretically, yes, but since 1982, it has not been put into practice.

Atadan

How did you find out that local varieties are more palatable than Serere Composite 2? Have you taken into consideration the possibility of farmers' bias in favor of local types?

Oyiki

The local variety is considered more palatable on the basis of the taste and color of the *ugali*. The two types were cooked and taste scores taken. The farmers said that local varieties provide white, more sticky, *ugali* with a good aroma. The question of bias is not to be ruled out, of course.

Rowland

Is the Serere Composite you have bristled or non-bristled?

Oyiki

Both.

Rowland

How does the local types and Serere Composite compare for ergot?

Oyiki

Serere Composite seems to be more resistant to ergot than the local ones.

SORGHUM IMPROVEMENT IN ETHIOPIA, 1984/85

Yilma Kebede and Abebe Menkir*

Sorghum is a dominant food cereal grown in almost all cropping regions of Ethiopia. It is grown in the high-, intermediate-, and low-elevation areas of the country. The major sorghum producing areas include the Chercher Highlands (east), the Kobo-Alamata plains (north), and the Humera-Teseni lowlands (north-west). Sorghum is particularly important in the lowlands of Ethiopia where rainfall is unreliable and erratic and crop failures are frequent. The lowlands of Ethiopia have been affected by recurrent drought for many years. Therefore, our first priority areas in the sorghum improvement program are the lowlands. Nationally, yield levels are below 1 ton/ha and are very much subject to the changes in the weather conditions and pest and disease hazards.

In breeding, development of good-grain-quality sorghum varieties and/or hybrids with stable and satisfactory yields for the major production zones is of paramount importance. Complementary to this is the need for emphasizing tolerance/resistance to moisture stress, standability and performance under minimum input. Agronomic work geared towards the efficient use of water and soil resources to maximize production in each major cropping zone is being pursued.

Appropriate control measures, with emphasis on resistant cultivars, are sought to combat a host of diseases, insects and weed problems. In addition, research work on the two most important crop protection problems, *Quelea* and *Striga*, would benefit from a regional effort.

The disciplines concerned in sorghum research in Ethiopia and areas of emphasis are presented in Table 1. During the 1984 season, 46 research activities related to various crop improvement disciplines (breeding, agronomy, crop protection and utilization) were planned by the sorghum research team. About 31 were executed and the rest were either not executed or no results were obtained due to various problems. Four trials in agronomy and soil fertility have been completed and conclusions and recommendations from these trials are being compiled. Rainfall and elevation data for the major research sites are presented in Annex 1.

***Team Leader and Research Officer in Sorghum Research, respectively. Institute of Agricultural Research, P.O. Box 103, Nazret, Ethiopia.**

Table 1. Sorghum research in Ethiopia

Major discipline/area	Research emphasis
Plant breeding and genetic improvement	- Hybridization, population stocks, pure line selection and F_1 hybrids - Screening of local and introduced germplasm
Tolerance/resistance to environment-induced stress	- Improved resistance (performance) to drought and other soil hazards - Standability and performance under minimum inputs
Agronomy	- Packages of production technology related to soil fertility, plant density, water conservation and mixed cropping
Crop protection	- Specific control mechanisms for pre and post-harvest pests - Reducing field losses due to insects, diseases and weeds - Control measures for combatting bird (*Quelea*) depredation and *Striga* damage
Food quality and processing	- Testing of food qualities of advanced lines
Farming systems research	- On-farm validation of research results.

BREEDING

Introduced trials and nurseries

A total of 489 entries received from ICRISAT, SAFGRAD, CIMMYT, Texas, and Tanzania were grown at Melkassa and Melka-Werer (off-season). Out of 357 entries evaluated at Melka Werer, 93 entries were promoted to the 1984 Lowland Preliminary Yield Trials which were planted at Melkassa and Mieso. A further 11 were advanced to the 1985 Lowland National Yield Trials. In addition, 25 entries identified at Melkassa were sown in the off-season for use as parents for the hybrid program.

Collection, evaluation, and utilization of indigenous sorghums

This past season, 603 accessions from the Plant Genetic Resource Center/Ethiopia (PGRC/E) were grown and evaluated at Arsi Negelia (high elevation) for relevant agronomic traits. Fiftyh-seven outstanding single plants tracing to 18 accessions were advanced for further evaluation.

Forty-six panicle samples representing the variability in the Ethiopian sorghum germplams collections were also maintained for reference purposes. About 700 entries from the lowland working collections, dating back to 1975, were rejuvenated and stored in a cold store provided by PGRC/E. Thirty-nine entries were reselected for additional observation and evaluation.

Sorghum Crossing Block

Sixty-one parents (12 high-, 5 intermediate-, 44 low-elevation types) were involved in 16 different combinations resulting in 359 out of a planned 393 crosses. The F_1 seeds from those crosses were sown in the off-season at Melka-Werer and 90% of the F_1s flowered between 66 and 76 days and the rest flowered in less than 66 days, which might make them potentially valuable for moisture-stress areas.

Pedigree breeding

A total of 439 F_2 populations and 556 F_3 families as well as 1,224 F_4 and 38 F_5 lines were grown at high (Alemaya, Arsi Neglie), intermediate (Bako, Dedessa, Jimma) and low (Mieso and Melkassa) elevations representing some of the major sorghum areas of the country. Of these, 214, 197, 211 and 17 crosses were advanced in the F_2, F_3, F_4, and F_5 generations, respectively.

Selections from different sites representing a similar ecological zone will be pooled to form the planting material for the ensuing crop season. Advanced generation family selections (F_4 onwards) with acceptable performance were advanced in the off-season and the best were subsequently put in observation or preliminary yield trials.

Hybrid sorghum breeding program

Two initial screenings, consisting of 148 and 38 hybrids each, were organized for low- and intermediate-elevation locations, respectively. The seed parents for the intermediate locations were converted B-lines from our program. Because of severe drought at low-elevation locations, it was not possible to successfully evaluate the potential of those hybrids. At intermediate-elevation locations, all pollinator lines turned out to be non-restorer (maintainer) lines).

An Elite Sorghum Hybrid Yield Trial, consisting of 16 hybrids having IS 10360A and ATX 623 as seed parents, was conducted at Melkassa and Mieso. Yields of hybrids obtained from Melkassa were very low (3 to 7 q/ha) because of severe moisture stress at anthesis and a poor experimental site. An Elite Sorghum Hybrids (ESH) yield trial and Initial Screening of Hybrids (ISH) will again be organized for low- and intermediate-elevation locations next season. Moreover, since seven years have elapsed since the program started, we plan to put some better hybrids in large-scale verification plots for comparison with varieties before recommending release.

Population breeding for the high and low elevation areas

For the highlands the dented hl marker is used to identify crosses. Plump seeds (crossed seed) from panicles selected at Alemaya and Arsi Negelie, 100 each, were handpicked and head rowed in the off-season at Dire Dawa and Melka-Werer, respectively. Dented seeds from segregating panicles selected in the off-season will be used as female rows at Alemaya and Arsi Negelie. Single-plant selections are put in progeny rows and subsequently into yield trials.

Two early-maturing sorghum populations received from Texas and a late maturing population developed by ESIP were grown at Melkassa. Male sterile panicles identified from one of the early type Texas populations (TP24) were crossed with early white seeded pollinators as well as red and brown ones in order to form two early populations.

Similarly, male sterile panicles identified from a population developed by the Ethiopian program were crossed with late maturing low-altitude-adapted elite entries and red and brown sorghum to form white seed as well as red and brown populations. These populations, plus two others, have been grown in the off-season for selfing. This activity will continue next season.

Sorghum off-season nursery operations

F_1s, selections from F_4 and F_5 generations, advanced lines from various trials and introductions, high and lowland populations, pollinator lines and seed parents, and several hundred entries received from SAFGRAD/ICRISAT were all sown at Melka-Werer, our off-season site. These materials are used for organizing different trials and breeding nurseries designed for high-, intermediate- and low elevation-locations.

Sorghum national, preliminary and observation yield trials

The objective in conducting these trials is to identify superior varieties both in terms of yield and other desirable traits (height, maturity, pest resistance, etc.) as well as wide adaptation. Mean yield and agronomic data for top yielding entries in the 1985 season are presented in Table 2.

Varietal differences in mean grain yield across locations (Alemaya and Arsi Negelie) varied from 23 to 43 q/ha in HAYT-1 (High Altitude Yield Trial) and from 14 to 36 q/ha in HAYT-2. From those trials, 11 entries outyielding the standard check variety, ETS2752, plus seven entries having high agronomic desirability scores and reasonable yields, were advanced to the High Elevation National Yield Trial for 1985.

Based on agronomic desirability score, disease resistance, and grain yield evaluations at Bako, Dedessa and Jimma, seven entries in observation Trial-1 producing over 50 q/ha and five entries in Observation Trial-2 producing over 38 q/ha were advanced to the 1985 Intermediate Altitude Sorghum National Yield Trial. Thirteen entries were also advanced to Intermediate Altitude Preliminary Yield Trial from a special trial planted at Bako.

From three lowland National Yield Trials (LNYT) conducted at nine locations, 15 varieties from LNYT-1 and 15 varieties from LNYT-2 and LNYT-3 were advanced to the 1985 Lowland National Yield Trials based on their performance at Melkassa only.

Table 2. Mean yield, days to flowering and plant height of three top yielding and check entries in low-, intermediate- and high- elevation locations, 1984.

	Yield (q/ha)	Flowering days	Plant height (cm)
Low Elevation			
81 ESIP36	22	71	103
82 LPYT-2£5	19	69	149
81 ESIP21	18	69	120
Melkamash (Std.Ck.)	9	70	121
* Mean	20	70	124
Intermediate Elevation			
84 MW 4135	60	95	153
84 MW 4131	57	102	138
84 MW 4130	57	101	138
Local Check	61	136	333
* Mean	58	99	143
High Elevation			
82 HNYT-2£1	43	108	181
82 HPYT-2£21	42	114	156
82 HNYT-2£20	41	112	168
ETS 2752 (Std.Ck)	35	116	220
* Mean	42	111	168

* Means do not include the check entries

In the Five Lowland Preliminary Yield Trials planted at Melkassa, Kobo and Mieso, 23 entries which showed good performance at Melkassa under irrigation were promoted to the 1985 Lowland National Yield Trials. A summary of the number of entries derived from the breeding program and included in various yield trials is given in Table 3.

In a red- and brown-seed sorghum variety trial tested at Melkassa, Debre Zeit, Wonji, Wolenchiti and Boffa, 13 varieties gave reasonable yields and had little or no bird damage. These varieties will have good potential for bird-prone areas. Among these were 3KX 72/1, Serena, and Seredo.

A preliminary observation involving a mixture of brown and white seed sorghums in different proportions (by volume) conducted at Melkassa revealed that birds could easily distinguish the white from the brown seeds in every mixture and adequate bird control could not be obtained.

Five elite entries from our program, along with ten other introduced entries which have been evaluated in the past few years, have been planted this season in verification plots (300 to 500 m^2) for final consideration for release.

Table 3. Number of entries derived from the breeding program and included in various yield trials conducted at high-, intermediate- and low-elevation locations, 1984

Trial	Program			
	Pedigree	Backcross	DSBM	Introduction
HAYT-1	15	11	-	-
HAYT-2	9	-	16	4
OT-1	16	-	-	-
OT-2	10	-	-	1
LNYT-1	3	-	-	20
LNYT-2	6	-	-	17
LNYT-3	11	-	-	12
LPYT-1	30	-	-	1
LNTY-2	-	-	-	35
LPYT-3	4	-	-	25
LPYT-4	-	-	-	13
LPYT-5	-	-	-	64
Total	104	11	16	192

DSBM - Dented Seed Breeding Method (Population Improvement Program)
HAYT - High Altitude Yield Trial
OT - Observation Trial
LNYT - Lowland National Yield Trial
LPYT - Lowland Preliminary Yield Trial

AGRONOMY

Sorghum population density trials

Varietal responses to increasing population densities were not consistent at Alemaya and Arsi Negelie. At Alemaya, the highest grain yields for ETS2752 and ETS4946 were recorded at 130,000 plants/ha, while that for Alemaya 70 was recorded at 70,000 plants/ha. At Arsi Negelie, while both ETS4946 and AL70 produced the highest grain yields at 160,000 plants/ha, ETS2752 gave the highest grain yields at 130,000 plants/ha. This trial is now considered as completed.

Population density trials conducted at Kobo, Mieso and Cheffa failed because of drought.

Sorghum/maize intercropping trial

At Arsi Negelie, the combined yields from intercrop combinations were higher than the sole crop yield of either sorghum or maize except that from broadcasting treatment. However, the results obtained at Alemaya were opposite to what was recorded at Arsi Negelie.

Sorghum and haricot bean intercropping trial

Intercropping depressed yields of haricot bean without significantly reducing the yield of sorghum. Yield reduction of haricot bean was more pronounced when it was intercropped with sorghum beyond the end of May. This trial was completed this past season.

The effect of intercropping sorghum with legumes

The sorghum plants, either as sole crop or in mixtures, failed to produce seeds due to drought. Although some seeds were obtained from the pulses (cowpea, haricot bean, mung bean) as sole crops or in mixtures, seed yield was abnormally low due to moisture stress. Generally, seed yield of sole pulses was greater than those in mixtures.

Dry matter and leaf area of pulses and sorghum as sole crops or in mixtures increased as planting density decreased. The effect of population density on the seed yield of the pulses in mixtures or as sole crops did not follow any particular pattern. The range in population density (pulses) used was 35,000 to 100,000 plants/ha.

The effect of tillage and cropping system

The objective of this experiment was to conserve the belg (small) rains by tillage methods (oxen, tractor, no-tillage) and use the residual moisture conserved during the belg to supplement the kremt (main) rains. Another objective was to study the effect of belg-sown mung bean on the seed yield of the subsequent kremt -sown sorghum. Unfortunately, however, the belg rains failedtotally. Hence, neither the belg rains could be conserved nor the mung bean sown as a precursor. As a result, almost all treatments had no significant effect on the parameters studied.

The effect of spacing and seed-bed preparation methods

Although intra-row spacing (5,10,15,20,25,30 cm) had no significant effect on plant height, dry matter/plot and leaf area/plot, dry matter/plant and leaf area/plant significantly increased in intra-row spacing (i.e. low plant density).

The effects of seed-bed preparation method on plant growth had a significant effect on dry matter per unit area. Plant growth was least for plants grown on flat ground. However, the tie-ridging treatments produced the greatest amount of plant growth, particularly in those grown in the furrows of the two types of tied-ridges (1 and 5m) apart.

None of the treatments produced seed yield due to drought.

The Effect of Planting Depth and Variety

The effect of planting depth (2,4,6,8 cm) on plant height, dry matter, leaf area, leaf area index (LAI) and seed yield showed no particular trend.

Although plant growth was greatest in Melkamash-79 followed by Gambella-1107 and 76-T1-23, seed yields of the three cultivars were in a reverse order. Thus, 76-T1-23 produced the highest seed yield followed by Gambella-1107 and Melkamash-79.

The effect of planting date

Since the rains ended earlier than expected, the early maturing varieties (76-T1-23 and Gambella 1107) produced higher grain yields than the relatively late-maturing one (Melkamash 79). However, dry matter accumulation and leaf area were greater for Melkamash 79 than for 76 T1-23 and Gambella 1107. Planting early in June was favourable for grain yield and other parameters.

NP fertilizer factorial trial

Soil types influenced the response of the sorghum variety ETS2752 to both N and P_2O_5 application. The highest grain yields obtained from Alemaya soil series (sandy clay loam residual soils) were recorded when 200 kg/ha N was combined with 75 kg/ha P_2O_5, while that obtained from Alemaya black soils (vertisols) was recorded when 250 kg/ha N was combined with 125 kg/ha P_2O_5. In general, increasing the level of both N and P_2O_5 was accompanied by a progressive increase in grain yield. Since moisture was limiting, tied-ridges enhanced the response of the variety to fertilizer application.

The effect of nitrogen and phosphorus fertilizers

None of the treatments produced seeds or had any significant effects on the parameters studied. The effects of the phosphorus and nitrogen fertilizers on all parameters did not follow any particular trend. However, there was a clear indication that plants grown in the furrows of tied ridges grew better than those on the flat ground.

Crop protection

The selection of sorghum varieties resistant to shootfly

Twenty entries received from ICRISAT plus four sorghums of intermediate maturity and two checks (Asfaw White and Didessa 1057) were tested for shootfly resistance. Although the number of plants with dead heart varied from 0 for PSF 12671 to 5 for IS 9521, proper screening of the varieties against shootfly was not successful due to a low level of shootfly infestation.

The use of trap crops to control African bollworm

Results revealed that the number of eggs and larvae counted on lupin were over three times greater than those counted on sorghum. The number of eggs and larvae counted on sorghum planted between the trap crop (lupin) were 6.5 and 5.4 respectively, while those counted on sorghum planted without lupin were 7.0 and 8.2, respectively.

Screening of sorghum varieties against downy mildew

Out of the 24 sorghum entries tested at Bako, only DMS 652 Naz 9 were infected by downy mildew. Susceptible maize cultivars were wiped out by this disease. In addition to scoring for downy mildew, the number of plants infected by honey dew was also recorded. Four entries, IS-643, Naz 8, Naz 13, and IS18757 had few infected plants.

Screening sorghum varieties for resistance/tolerance to Striga

All entries (18) tested at Beles in _Striga_ infested-plots had few _Striga_ counts/sorghum plant (0.1 to 11) except Gambella 1107 and Melkamash 79 (31 each). Of these, nine entries which had less than 0.5 _Striga_ counts/sorghum plant and good agronomic appearance score will further be tested at various locations where _Striga_ is a serious problem.

Assessment of crop-loss due to weed competition

The results of this trial showed that weeds other than _Striga_ can cause 85% yield loss in sorghum. The most critical period of weed competition appeared to be between three and four weeks after sowing. Since the drought affected the trial considerably, yield levels were very low.

The effect of different herbicides with and without sorghum safener

The efficiency of both Primagram and Gesaprim (3 to 5 l/ha of product) in controlling weeds early was generally satisfactory. These herbicides did not persist for more than four weeks. At Melkassa both Primagram and Gesaprim applied with safener caused no visible damage to the crop. However, yields were very low and did not show any consistent trend because of the drought that occurred during the growing season.

At Bako, Primagram (1.5 and 2 kg/ha a.i.) applied without safener reduced grain yield considerably compared to application with safener. However, application of Gesaprim and Primextra with safener showed some yield reduction.

Chemical control of weeds in sorghum

Primagram, Primextra, Gesaprim, and Terbutryne applied at the rate of 1.75 kg/ha a.i. each were found to be as effective as hand weeding. Eradicane had a high phytotoxic effect on sorghum.

CONCLUSIONS

The full potential of varieties/hybrids and treatments could not be realized this past season due to moisture-stress conditions, particularly in the low elevation areas of the country.

The recurring drought has once again made it necessary to chart appropriate and immediate short-term measures. Our emphasis should undoubtedly shift towards developing short-season drought-tolerant types with complementary production practices.

Moreover, stand establishment, Striga and Quelea need to be addressed as well. We plan to screen varieties for standability and also look at brown sorghums which may tolerate bird damage and possess acceptable food-making qualities. Screening of varieties for Striga resistance will continue. Agronomic work related to soil improvement and water conservation will command top priority.

Annex 1

Rainfall (1984) and elevation data of sorghum research sites.

Location	Rainfall (mm)		Altitude (m)
Alemaya	564	(900)*	1,980
Arsi Negele	**410	(1,150)	1,960
Bako	1,050	(1,200)	1,650
Dedessa	-	(1,340)	1,450
Jimma	1,245	(1,530)	1,750
Kobo	240	(650)	1,500
Mieso	369	(700)	1,470
Melkassa	512	(800)	1,550
Melka Werer	424	(650)	750

*Rainfall figures in brackets are long-term averages.

**May-September

Annex 2

Contributing personnel - sorghum research, 1984/85

Name	Station	Discipline
Abuhay Tekele	Kobo	Agronomy
Benti Tolessa (Dr.)	Bako	Agronomy/Breeding
Kebede Mulatu	Bako	Agronomy
Gebregziabher Andie	Jimma	Agronomy
Adjei-Twum (Dr.)	Nazret	Agronomy/Physiology
Kidane Giorgis	Nazret	Agronomy
Nigusse T. Michael	Nazret	Agronomy
Tamirie Hawando (Dr.)	Alemaya (AAU)	Soil Fertility
Abraham Tadesse	Bako	Entomology
Mesfin Tessera	Bako	Pathology
Rezene Fessahaie	Holetta	Weed Control
Ahmed Sherif	Nazret	Weed Control
Etagegnehu G.Mariam	Nazret	Weed Control
Dawit Mulugetta	Bako	Weed Control
Aberra Deressa	Nazret	Agronomy
Yilma Kebede (Dr.)	Nazret	Breeding
Abebe Menkir	Nazret	Breeding

Relevant agronomic and yield data were recorded from each plot. A combined analysis of variance across years was computed for grain yield. Since the performance of the two sorghum varieties was more or less similar from year to year, the grain yield and stand count for each intercrop combination was averaged over those two sorghum varieties. Land equivalent ratio (LER) was calculated as:

$$LER = \frac{\text{Sorghum yield in mixture}}{\text{Sorghum yield in pure stand}} + \frac{\text{Maize yield in mixture}}{\text{Maize yield in pure stand}}$$

Results and discussion

As shown in Figure 1, yields of intercropped sorghum and maize were significantly lower than those of the respective sole-crop. The reduction in both sorghum and maize yields was more pronounced when intercropping was done in alternate rows at Alemaya. At Arsi Negelie, however, the decrease in sorghum yield was more pronounced when a mixture of sorghum and maize seeds was broadcast. These reductions in yield of the component crops could possibly be due to competition between the two crops and the low population densities of both sorghum and maize in each intercrop combination (Fig.1). The relatively high yield of intercropped maize recorded at Arsi Negelie compared to that at Alemaya might have resulted from the high population densities of maize maintained at Arsi Negelie (Table 2) and also varietal differences.

The combined yields from intercrop combinations were higher than the sole-crop yield of either sorghum or maize at Arsi Negelie (Table 2). However, yield advantages obtained from broadcasting a mixture of maize and sorghum were not high since the actual population of sorghum attained in the field (21,400 plants/ha) was lower than expected (27,000 plants/ha). The highest combined yields recorded from intercropping sorghum with maize within a row could be ascribed to the relatively high population densities of the component crops (Table 2 and Fig.2).

At Alemaya, the total yields obtained from all intercrop combinations were higher than the sole-crop yields of either sorghum or maize, except from intercropping in alternate rows (Table 2). Contrary to what was recorded at Arsi Negelie, the highest total yield was obtained from broadcasting a mixture of maize and sorghum. A mixture of high-population-density late-maturing sorghum and low-population-density early-maturing maize might have minimized the competition between the component crops in this cropping system (broadcast).

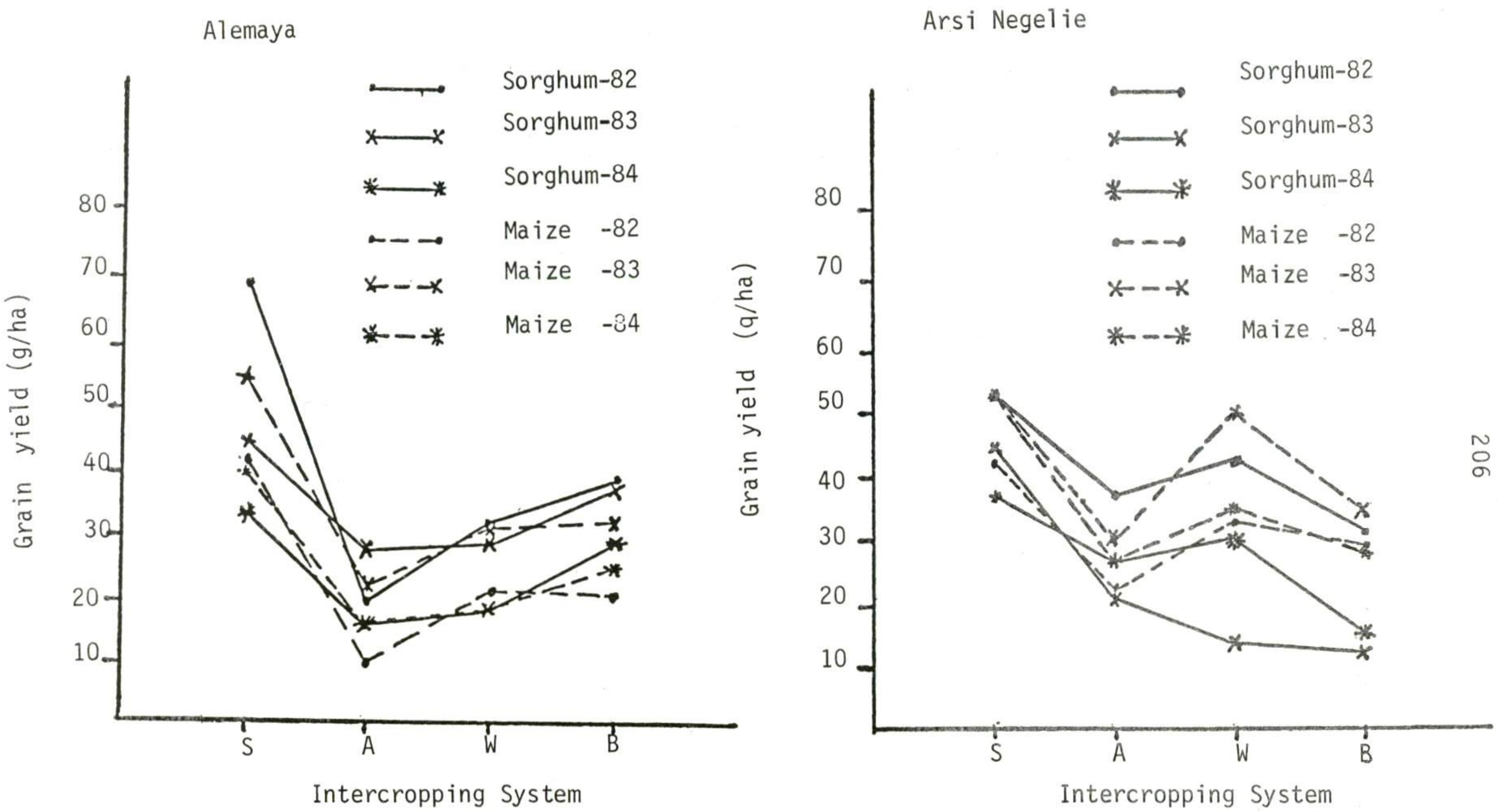

Fig. 1 Mean grain yield of sorghum and maize in different systems of intercropping: A - alternate rows, W - within a row, B - broadcasting a mixture of sorghum and maize and S - sole cropping

The land equivalent ratio (LER) showed that sorghum was more competitive than maize at Alemaya while the reverse was generally the case at Arsi Negelie (Table 2). Yield advantages of intercropping varied from 8 to 29% for Alemaya and 9 to 46% for Arsi Negelie. The maize cultivars used were shorter (<200 cm) and earlier (110-130 days to maturity) than the sorghum varieties (230-280 cm in height and 170-190 days to maturity). Such differences in height and maturity of the component crops might have contributed to the yield advantages obtained from intercropping. Intercropping an early-maturing crop (maize) with a slow-growing and late-maturing one (sorghum) minimizes competition between the component crops during the reproductive stage of growth (Baker, 1979) and promotes better use of resources over time (Andrews, 1972; Hawkins, 1984; Osiru and Willey, 1972; Willey and Osiru, 1972). The results of these trials revealed the possible importance of this effect at both Alemaya and Arsi Negelie where considerable yield advantages were recorded when early maturing maize varieties were intercropped with late maturing sorghums. Besides, the level of population densities of the component crops had influenced yield advantages derived from intercropping sorghum with maize.

In summary, intercropping late-maturing sorghum with early-maturing maize appeared to be advantageous both under a low level of management (broadcasting) and improved production technology (row planting). Therefore, there appears to be good justification for farmers continuing their system of intercropping using compatible varieties of maize and sorghum.

REFERENCES

Andrews, D.J. 1972. Intercropping with sorghum in Nigeria. Expl. Agric. 8:139-150.

Baker, E.F.I. 1979. Mixed cropping in Northern Nigeria.III Mixtures of cereals. Expl. Agric. 15:41-48.

Brhane Gebrekidan. 1976. Intercropping with sorghum at Alemaya, Ethiopia. In J.H. Monyo, A.D.R. Ker and M. Cambell (eds.). Intercropping in semi-arid areas. University of Dar es Salaam, Morogoro, Tanzania, and IDRC, Ottawa, Canada.

Jodha, N.S. 1977. Resource base as a determinant of cropping patterns. ICRISAT Economics Program Occasional Paper 14, Hyderabad, India.

Hawkins, R. 1984. Intercropping maize with sorghum in Central America: A cropping system case study. Agric. Systems 15: 79-99.

Miller, L.F. and Tilahun Makonnen. 1965. Organization and operation of three Ethiopian case farms. Alemaya, Ethiopia. Alemaya College of Agriculture Experiment Station Bulletin No.35.

Osiru, D.S.O. and Willey, R.W. 1972. Studies on mixtures of dwarf sorghum and beans (Phaseolus vulgaris) with particular reference to plant population. J. Agric. Sci. 79: 531-540.

Willey, R.W. and Osiru, D.S.O. 1972. Studies of mixtures of maize and beans (Phaseolus vulgaris) with particular reference to plant population. J. Agri. Sci. 79: 517-529.

Willey, R.W. and Rao, M.R. 1981. Genotype studies at ICRISAT. In R.W. Willey and C. Garver (eds.), Proceedings of the International Workshop on Intercropping. 10-13 January 1979. Hyderabad, India.

Yilma Kebede. 1977. Aspects of sorghum management and production. Paper presented at the Workshop on Sorghum Improvement in Ethiopia. 27-29 October 1977, Nazreth, Ethiopia.

PAPERS ON ETHIOPIA

DISCUSSION

Bawazir

To save time and labor, why don't you use hot water emasculation instead of hand emasculation in sorghum?

Yilma

Hand emasculation is simpler and less cumbersome and a more assured way of making good and useful emasculation. Under our conditions the time and labor involved are not all that excessive compared to the importance of the job.

Alahaydoian

I agree that the hot water system of emasculation is cumbersome. One needs to heat the water, have a source of heat in the field, and have good temperature control. The length of time needed for head treatment is also critical. Moreover, the sequence of flowering of the head leads to a high probability of selfed seed. Therefore, hand emasculation is the surest and most reliable method of getting crossed seeds.

Brhane

In the eastern Africa region hot water emasculation is largely used in the Uganda Program. Could we hear their comment on this?

Zake

The hot water emasculation technique is used in sorghum and finger millet at Serere. We get more successful crosses in sorghum than in finger millet. The materials you require are a thermometer, polythene tubes, cooking pots, rubber bands and a stop watch.

A polythene bag with both ends open, is slipped over the selected head of sorghum and a rubber band is used to tie the bottom end of the polythene bag to the peduncle of the sorghum head. Water is heated to 46^{0}C and poured into this bag so that the whole head is emersed. The temperature of 46^{0}C is maintained for ten minutes. Water leakage is experienced as one cannot tighten the peduncle too much, but additional water should be added and the thermometer used to stir the water. Finger millet is treated in the same way, except 52^{0}C 2 minutes was used after carrying out experiments with ranges of temperature and time required.

Mwaule

In view of your erratic rainfall in Ethiopia, what is the place of hybrid sorghum inthe country? Under adverse conditions, total crop failure may be possible because of the uniformity of hybrids.

Yilma

No. It has been amply demonstrated in papers presented in this workshop (Doggett and Rowland) that hybrids have that extra advantage of performing better than varieties under adverse conditions. Besides, adaptation to such conditions is one selection criterion.

Mwaule

Would you comment on the preponderance of agronomists and breeders relative to entomologists and pathologists in the Ethiopian program?

Yilma

It is a situation we are worried about and we are trying to balance the disparity, especially with regard to crop protection personnel.

THE SORGHUM IMPROVEMENT PROGRAM IN SOMALIA

E.K. Alahaydoian*

The Sorghum Improvement Program of Somalia (SIPS) is centered at Baidoa, Bay Region. The Bay Region, with its four districts, is one of the major production regions for sorghum. Sorghum is a rainfed crop in Somalia. Wherever irrigation water is available farmers prefer to grow maize.

Of the two seasons per year, the Gu (April-July) season is the more important because the rains are more intense and more reliable. The long term average for Gu is approximately 350mm, and for the whole year approximately 600mm.

The aims of the SIPS are to develop higher yielding varieties than the local ones with good drought tolerance and resistance to stem borers. Good cooking quality is an additional requirement of the new varieties.

In view of these aims the work of the 1984 season consisted of activities in agronomy, breeding, and entomology.

Agronomy

The 1984 Gu season was marked by scant rains and reduced emergence of plants. The total precipitation during the 1984 Gu amounted to 274mm, of which 219mm fell during April-May, the period of vegetative growth.

Agronomic studies consisted of yield and plant-population trials.

A large number of lines were tried during the 1984Gu season. For ease of handling we divided these lines into 19 nurseries with a maximum of 25 lines in each.

The growing conditions were very bad all the way from germination to harvest. In some cases we had to discard entire nurseries and in others we had to reduce the number of planned and planted entries.

---

*Advisor, Somali Government Sorghum Improvement Program, c/o Bay Region Agricultural Development Project, P.O. Box 2971, Mogadishu, Somalia

Some of the causes of the low germination achieved were uneven depth of planting, uneven soil compaction and, of course, poor seed quality. During the vegetative cycle and in the post-flowering period, the crop was attacked successively by stalk-borers, leaf-eating insects and birds. In addition to the above, the crop was under severe moisture as well as fertility stress.

In general yields were very low compared to previous seasons. The yield of the local check varied from 33 kg/ha to 630 kg/ha over all the experiments, whereas its range in the entomology experiments was 33 to 229 kg/ha. It is impossible for us to pinpoint the causes of such low yields of the local and experimental lines in the entomology experiments, especially since they were sown on fallowed land.

Nevertheless, certain varieties performed comparatively better. These included 12 lines from the ISDRON-80 set, 2 varieties from Egypt, 2 lines from Upper Volta, 4 lines from ISVAT-83, and 7 lines from Uganda. The grain yields of these are summarized in Table 1.

In all our trials and nurseries, the coefficients of variability are much higher than desirable. The range is usually from 50% to 170%, reducing the scientific value of our results. Such variability is due to the great variability of the plant micro-environment, especially the soil. The absence of fertilizer and organic manure in our cultural practices contributes to the soil's variability. The argument for continuing trials without fertilizer is that the farmer cannot afford fertilizer. The usual lack of suitable insecticide when it is needed is another factor contributing to the variability.

Certain sets like ISDRON-80 and ISPYT-1, both from ICRISAT, have been tried over several seasons and covering a variety of environments. We believe it is possible for us to attempt selection. Over the seasons we have eliminated a few entries but no real selection was ever done. Calculations are under way to determine the entries to be advanced. The criteria to be used are yield and stability. We intend to go into on-farm trials with selected lines, though we might need a season for seed increase.

Our counterparts, Mr. Aden Ossoble and Mr. Abdulkadir Samatar, were in charge of the plant-population experiments. Two varieties, GPR 148 and the local one, were tested in a split plot design at four densities, 38,000, 41,000, 53,300 (2 plants/hill) and 53,300 (1 plant/hill). In GPR 148 the yields ranged from 102 to 118 kg/ha, except for 38,000 pl/ha density which yielded 77 kg/ha.

Table 1. Yield of some outstanding lines at Bonka, Somalia in the 1984 Gu season

Designation	Yield (kg/ha)	Origin
71020	978	ISDRON-80
71306	791	ISDRON-80
71205	750	ISDRON-80
71684	618	ISDRON-80
71916-2	1,032	ISDRON-80
71506-2	425	ISDRON-80
71383-1	864	ISDRON-80
71249-1	790	ISDRON-80
71249-2	763	ISDRON-80
71260	768	ISDRON-80
7124-1	798	ISDRON-80
71422-2	655	ISDRON-80
Giza-3-R	953	Egypt
IS 2870	616	Egypt
37-1	1,005	Upper Volta
36/86-1	638	Upper Volta
ICSV 147	796	ISVAT-83
ICSV 153	439	ISVAT-83
ICSV 137	368	ISVAT-83
ICSV 149	348	ISVAT-83
SDX 135/13/1/3/1/2	857	Uganda
SDX 135/13/1/3/1/4	574	Uganda
SDX 135/13/1/3/1/1	464	Uganda
Himidi	623	Uganda
4MX 11/9/2	577	Uganda
4MX 249 wh.	490	Uganda
4MX 123	460	Uganda
Local	33 to 630	Somalia

The yields of the local check varied from 127 kg/ha for the 53,300 (1 plant/hill) population to 160 kg/ha for the 41,000 plant/ha population. No statistically significant differences could be detected and the C.V.s were 83% and 48%, respectively, for GPR 148 and the local check.

During the 1984 Deyr only GPR 148 was tested with the same densities. The yields varied between 240 kg/ha for the 53,300 plants/ha (2 plants/hill) density to 196 kg/ha for the 53,300 plants/ha (1 plant/hill) with no significant differences and a C.V. of 31%.

It was difficult to establish the desired population densities, especially at wider spacings. Now that an experimental plot planter is available we might repeat this experiment varying our method of population establishment by thinning instead of direct sowing.

Plant breeding

The breeding program consisted of backcross, exotic x local crosses, A and R lines, and F_2s from the ISHAT set.

About 200 F_2s resulting from crosses between exotics and locals were to be backcrossed to their local parents.

A certain number of exotic top yielders selected from different nurseries were to be crossed with six local lines.

Six A-lines were to be crossed with 11 R-lines for selection in the field. These lines were sent to us from Texas A & M University.

The male sterile segregants of the F_2s from the ISHAT-82 set were to be crossed with selections from the field.

The poor germination, limited amount of precipitation, and our inability to irrigate the trials and nurseries, caused us to cancel this important section of our program.

Some parts of the crossing program were repeated during the Deyr season and most of the crosses were performed. The planned backcrosses are to be done during the next Gu season.

Entomology

The most important pest in the sorghum growing areas of Somalia is the stalk-borer, *Chilo partellus*, followed by the shoot fly, *Atherigona soccata*, and in the humid areas the midge *Contarina sorghicola* is of concern.

Our seven entomology nurseries dealt with these insects. The germplasm at our disposal for these purposes was received from ICRISAT. As previously stated, the grain yield of the lines in the entomology nurseries was rather low. IS 4664, IS 5470, IS 18584, and IS 5585 from the shootfly nursery and CSH-1, IS 4329, IS 17853, and IS 5538 from the stem-borer nursery performed relatively well. The only line in the midge nursery which performed somewhat better was DJ 6514.

We had many missing values not only because of the germination problems but also because we lost many harvested bundles from our store. The stalks are normally cut in the field, bundled, tagged and brought to a shelter. Since we do not have a decent workshop or a secure place where we can store our harvests, the bundles which are stored in the open are moved and the bindings are undone by wind, releasing the stalks or the tags. With the new facilities under construction we hope most of these problems will soon be corrected.

In the stem-borer nursery the local entry suffered 56% damage. PS 21119, PS 8313 and IS 18577 suffered 26%, 44%, and 45% borer damage, respectively.

In the shootfly nursery, the local check had 53% damage whereas IS 18577, IS 4664 and PS 21239 had only 35%, 38%, and 45% damage, respectively.

In the IDIN nursery the damage suffered by GPR 148 was 32%. PM 7061 and PM 7495 of the midge nursery had 57% and 50% damage, respectively.

Certain lines from the stem-borer and shootfly nurseries have been tried for a second season. Those that have performed well will be used in our crossing block.

During the 1984 Gu season we delivered the record books of the International Sorghum Stem Borer Nursery 82 and the International Sorghum Midge Nursery 82 to the Afgoy station where the crop suffers from these two pests. Neither the insect damage nor the yield data were reported back to us. The *Quelea* and the weavers feasted on the grain of these nurseries.

Eastern Africa Cooperative Sorghum Regional Trials

A set of 10 lines was received in the 1983 Gu from the SAFGRAD/ICRISAT Eastern African Program. These were sown at Bonka in four replications. The yields are given in Table 2.

Table 2. Grain yield of the Very Dry Lowland Set of the Eastern Africa Cooperative Sorghum Regional Trial, Bonka, Gu 1983 and 1984.

	Grain yield (kg/ha)	
Entry	Gu 1984	Gu 1983
5DX 135/13/1/3/1	465	-
3KX 76/5	423	568
3KX 71/1	421	-
3KX 72/1	369	408
MUKUENI	353	163
76 TI-23	331	-
GHARIB white	311	-
GHARIB Red	310	438
3KX 73/4	269	615
DB 822	146	-
Local	358	275
Mean	341	
C.V., %	58	

We did not find significant differences between the local and the other entries.

ACKNOWLEDGEMENT

We have received and continue to receive germplam and suggestions from many sources. Our sincere thanks go to all those who have helped us in one way or another. Thanks are also due to SAFGRAD and IDRC who have made possible this and a previous meetings of eastern Africa sorghum workers.

GENE EFFECTS FOR RESISTANCE TO STEM BORER IN SORGHUM

Hussain Mao Haji*

Sorghum is one of the major staple cereal crops in the semi-arid tropics (SAT). Over 55% of the total world sorghum area is in the SAT. Of the total sorghum production in the SAT, nearly 65% is produced in Africa and Asia (Swindale, 1982). Grain yields on the peasant farms in these areas are generally low at 500-800 kg/ha (Seshu Reddy, 1982) and one of the major yield-limiting factors is insect pests.

Insect pests cause nearly 14% loss in the total sorghum yield (Cramer, 1967). If one takes into account the damage caused by other pests such as nematodes, slugs, mites, and vertebrates such as rats and birds, the losses may exceed 25% of total production (Belum, 1983).

Sorghum is vulnerable to over 150 insect species from sowing to the final crop harvest and stem borers are the major pests worldwide (Seshu Reddy and Davies, 1979). There are several species of stem borers which attack sorghum and they vary in the different sorghum-growing regions (Young and Teetes, 1977). Chilo partellus is a serious pest of sorghum in India (Jotwani and Young, 1972) and in the low-lying areas of eastern Africa (Ingram, 1958), while in West Africa and in the highland areas of East Africa Busseola fusca is the predominant species.

Chilo partellus (Swinhoe) attacks sorghum from two weeks after germination until harvest and affects all plant parts except the roots. The first symptom of attack is the irregularly shaped holes caused by the early instar larvae feeding in the leaves. The larva then bores into the stem at the base and reaches the growing point. It cuts the growing point causing the characteristic "dead-heart" symptom. In situations where the larva is not able to reach the growing point, it continues to feed inside the stem causing extensive tunnelling. It also tunnels the peduncle and extends up to the ear-head. It completes its life-cycle in about a month under optimum environmental conditions and three to four generations are usually completed in a crop season.

---

*Plant Breeeder, Ministry of Agriculture, Mogadishu, Somalia.

Several strategies have been thought of to control this pest. Cultural methods such as destruction of crop residues, timely sowing, and removal of alternate hosts have been used to minimize the incidence of this pest but have met with little success (Jotwani, 1982). Considerable information is available on the natural enemies of stem borers (FAO, 1979). However, a systematic program on the biological control of these pests has not been undertaken (Jotwani, 1982). Insecticidal control measures are available, but are not very popular due to their cost, toxic hazards, unfamiliarity and non-availability to the farmer (Agrawal et al., 1983). Breeding resistant cultivars appears to be the safest way of stabilizing production under low input management conditions (Agrawal et al.,1983).

Very little information is available on the genetic aspects of stem borer (Chilo partellus) resistance in sorghum. Rana and Murty (1971) reported that resistance to stem borer was polygenically inherited. Resistance to primary damage (leaf feeding) was found to be governed by additive and additive x additive type gene action, while additive and non-additive type of gene action was important for secondary damage. Kulkarni and Murty (1981) studied the nature of gene action for stem borer resistance in F_2s and F_3s in a six varietal diallel set of crosses and noticed significant GCA and SCA variances in both F_2s and F_3s, which indicated that both additive and non-additive components influenced stem-borer resistance. However, the higher magnitude of GCA in F_3 indicated that stem-borer resistance was predominantly governed by additive and additive x additive components of genetic variance.

A detailed knowledge on the genetic aspect needs to be generated to help in manipulating resistance genes and thus accelerating the pace of resistance breeding against this pest. As a consequence of this situation, a study was conducted by ICRISAT in India during 1982-1984 to examine the gene action for resistance of sorghum to stem borer.

MATERIALS AND METHODS

The experimental material consisted of six generations of five crosses: parents (P_1 and P_2, F_1s, F_2s), and the backcrosses (CB_1 and BC_2). In the designation of a cross, the female parent was considered as P_1 and the male parent as P_2. These crosses were generated by using six sorghum cultivars. Cultivars SPV 351, SPV 422 and SPV 386 were borer susceptibles (S) whereas IS 2205, PB 8104-1 and PB 8272 were moderately resistant (M). The crosses required for this study were made during the 1982 rainy season at ICRISAT Center, Patancheru, India. Subsequently, they were advanced and backcrossed (both ways) at Patancheru in the following post-rainy season.

The genetic material generated for this study was evaluated under natural infestation at Hissar during the 1983 rainy season as well as under artificial infestation (inoculated 15 days after germination) at Patancheru during the 1983-1984 post-rainy season. The experimental sets at Hissar and Patancheru consisted of five and seven crosses, respectively.

At Patancheru, plants were inoculated with artificially reared larvae at the rate of 5-7 first-instar larvae in the whorl of the plant.

The experiments were conducted using three replications in a compact family block design. The experiment at Hissar was fertilized with 40 kg N and 40 kg P_2O_5/ha before planting. The rows were spaced 60 cm apart and the plants within rows 10 cm apart. The experiment at Patancheru was fertilized with 84 kg N and 84 kg P_2O_5/ha before planting. The rows were spaced 75 cm apart and plants within rows were spaced 10 cm apart. The F_2s were planted in four rows, backcrosses in two rows and parents and F_1s in a one-row plot 3m in length. Stem-borer incidence was recorded as per cent dead-hearts which were later transformed by the arcsin scale and expressed in grades.

The various gene effects were estimated using Hayman's (1958) six-parameter model. The significance of the genetic effects was tested in the same manner as carried out by Hayman and Mather (1955) in their scaling tests.

RESULTS

Estimation of gene effects (Hissar)

The transformed mean per cent stem borer dead-hearts for six generations (P_1, P_2, F_1, F_2, and BC_2) by crosses are presented in Table 1. The M x M cross had comparatively less borer damage than the M x S or S x M crosses indicating the existence of resistant genes for stem-borer reaction. The F_1s were much closer to their female parent than to their male parent. In F_2, the damage sustained decreased in crosses No. 1, 4, and 5 and increased in the other two. In general the BC_1s and the BC_2s were toward their recurrent parent.

The estimates of different gene effects for stem borer dead-hearts (Table 2) indicate the importance of additive gene effects in cross 2 and dominant gene effect in cross 5. Dominance gene effects were of higher magnitude than additive and epistasis effects. None of the epistatic gene effects were shown to be significant.

Table 1. Transformed mean per cent stem borer dead-hearts of the parents and segregating generations at Hissar

Cross			P_1	P_2	F_1	F_2	BC_2	BC_2	M.S.	C.D.	Deviation over mid-parent
PB-8104-1 (M)	x	IS-2205 (M)	46.9	29.7	43.4	38.4	44.0	37.3	113.1	6.2	5.1
PB-8104-1 (M)	x	SPV-351 (S)	53.2	74.8	47.1	59.7	42.4	64.6	425.1	6.8	-16.9
SPV-386 (S)	x	IS-2205 (M)	76.5	48.7	68.7	71.2	75.4	67.5	306.4	7.8	6.1
SPV-422 (S)	x	IS-2205 (M)	78.2	40.7	64.2	55.9	65.1	53.8	481.3	7.4	4.8
SPV-351 (S)	x	IS-2205 (M)	85.9	35.1	79.8	54.4	69.1	60.4	1016.7*	9.6	19.3

Generation: P_1 – BC_2

M = Moderately resistant
S = Susceptible
* Significant at the 0.05 probability level

Table 2. Estimates of gene effects for stem borer percent dead-hearts (transformed data) at Hissar

Cross	Gene effect					
	m	a	d	aa	ad	dd
PB-8104-1 x IS-2205	38.45***	6.05	15.41	10.19	-2.61	-10.69
PB-8104-1 x SPV 351	59.78***	-22.22***	-41.82*	-24.95	-11.46	33.04
SPV-386 x IS-2205	71.24***	7.89	7.38	1.27	-5.98	-24.64
SPV-422 x IS-2205	55.96***	11.33	19.04	14.20	-7.38	-4.52
SPV-351 x IS-2205	54.49***	8.72	60.54**	41.24*	-16.68*	-19.73

*, **, *** Significant at the 0.1, 0.05 and 0.01 probability levels, respectively.

Estimation of gene effects (Patancheru)

The transformed mean per cent stem borer dead-hearts for six generations (P_1, P_2, F_1, F_2, BC_1, and BC_2) by crosses are presented in Table 3. The F_1s of PB 8104-1 x IS 2205 and PB 8104-1 x SPV 422 crosses did not differ significantly from their mid-parental value indicating the incomplete dominance for borer reaction. F_1s of SPV 386 x IS 2205 and SPV 351 x IS 2205 crosses did not differ significantly from their male parent. F_1 of PB 8104-1 x SPV 351 cross showed a tendency towards its male parent while SPV 422 x IS 2205 and PB 8272 x SPV 351 crosses were towards their female parent. F_2s of PB 8104-1 x IS 2205 and SPV 351 x IS 2205 crosses sustained less damage while in the rest of the F_2s the damage increased. In general BC_1 and BC_2 are not in accordance with their recurrent parent.

The estimates of different gene effects for stem borer dead-hearts are given in Table 4. Dominance, additive x additive and additive x dominance were significant (positive) in PB 8104-1 x IS 2205 cross. Significant additive (positive) and epistatic gene effect (negative) of additive x dominance and dominance x dominance were evidenced in PB 8104-1 x SPV 351 cross. Dominance and epistatic gene effects were significant (positive) in SPV 351 x IS 2205 and PB 8104-1 x SPV 422 crosses except for dominance x dominance being negative.

DISCUSSION

A general view of generation means of different crosses M x M, M x S, S x M) reveals that the M x M type of cross had comparatively less borer damage than the crosses involving a susceptible parent, indicating the existence of resistant genes. Such differences did not exist under artificial infestation. This may have been due either to comparatively lower borer pressure under natural infestation or to the possibility of all the mechanisms of resistance operating against the insect under natural conditions.

Table 1 indicates the tendency of the performance of F_1 progenies to lean towards the female parent, irrespective of its resistance. This could be an indication of cytoplasmic influence. This observation needs to be investigated further as reciprocal crosses were not involved in the present study.

Table 3. Transformed mean per cent stem borer dead-hearts of the parents and segregating generations at Patancheru

Cross	Generation						Generation M.S	C.D.	Deviation over mid-parent
	P_1	P_2	F_1	F_2	BC_1	BC_2			
PB 8104-1x IS 2205 (M) x (M)	59.4	93.8	77.1	57.2	84.8	71.1	611.7**	6.2	0.5
PB 8104-1 x SPV 351 (M) x (S)	100.0	65.7	78.0	84.8	100.0	91.8	539.1**	6.0	-4.8
SPV 386 x IS 2205 (S) x (M)	86.9	55.6	57.2	76.5	86.2	78.4	577.5*	6.7	-14.0
SPV 422 x IS 2205 (S) x (M)	80.7	72.1	78.5	68.8	74.4	79.5	65.0	8.2	2.1
SPV 351 x IS 2205 (S) x (M)	69.8	90.6	88.9	74.1	96.1	89.7	325.6	6.1	8.7
PB 8104-1xSPV 422 (M) x (S)	58.9	90.2	74.9	79.0	95.4	87.8	521.1**	5.8	0.4
PB 8272 x SPB 351	70.6	80.0	61.2	68.2	85.9	77.6	239.3	6.4	-14.1

M = Moderately resistant
S = Susceptible
*, **, Significant at the 0.1 and 0.05 probability levels, respectively.

Table 4. Estimates of gene effects for stem borer percent dead-hearts (transformed data) at Patancheru

Cross	Gene effects m	a	d	aa	ad	dd
PB 8104-1 x IS 2205	57.29***	13.62*	83.39**	82.88**	30.81**	-87.40*
PB 8104-1 x SPV 351	84.92***	8.02**	39.41	44.31	-9.04	-106.31**
SPV 386 x IS 2205	76.84***	7.53	9.42	23.36	-7.83	-95.94
SPV 422 x IS 2205	68.94***	-5.03	35.90	32.66	-10.44	-30.94
SPV 351 x IS 2205	74.16***	6.30	83.78**	75.12***	16.74**	-106.60**
PB8104-1 x SPV 422	79.07***	7.57	50.80**	50.42**	23.17**	-117.96**
PB 8272 x SPV 351	68.30***	7.89	40.55	54.68	12.60*	-109.18

*, **, *** Significant at the 0.1, 0.05 and 0.01 probability levels respectively.

The values for BC_1 and BC_2 for the naturally infested experiment at Hissar (Table 1) were towards their recurrent parent. The values of BC_1 and BC_2 for the artificially infested experiment at Patancheru (Table 3) were not in accordance with the respective values of their P_1 and P_2 which could be due to the absence of ovipositon non-preference which is eliminated with artificial inoculation. The presence of an antibiosis mechanism alone might not be sufficient to explain the trend of the BC_1s and BC_2 towards their recurrent parent.

The estimates of the six parameters for the various gene effects indicate the dominance and epistatic gene effects contributed more to stem-borer reaction under artificial infestation. In such a situation, if any genotype shows resistance, it will be due either to antibiosis or mechanical barriers in the whorl. It appears that the epistatic gene effects control the antibiosis mechanisms.

Additive gene effects could be fixed in a random mating population by resorting to mass selection, recurrent selection for general combining ability or full sib family selection in the F_2 generation. The PB 8104-1 x SPV 351 cross may be chosen for improvement by selection as it showed maximum negative additive effect. The PB 8104-1 x SPV 351 cross also showed a maximum negative dominance component of gene effect. Resistant parents involving this cross may be used in the development of a resistant hybrid.

LITERATURE CITED

Agrawal, B.L., Taneja, S.L., Sharma, H.C., Maiti, R.K., Leuschner, K., Mukuru, S.Z. and House, L.R. 1983. Sorghum improvement for pest resistance at ICRISAT. Paper presented at the National Seminar on Breeding Crop Plants for Resistance to Pests and Diseases, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India.

Belum V.S. 1983. (unpublished). Host-plant resistance to insect pests: Principles. Lecture presented to the students at Andhra Pradesh Agricultural University, Rajendranagar, Hyderabad (unpublished).

Cramer, H.H. 1967. Plant protection and world crop production. Bayer, pflanzescutz, Leverkusen.

Food and Agriculture Organization. 1979. Elements of Integrated Control of Sorghum Pests. FAO, Rome, Italy.

Hayman, B.I. 1958. The separation of epistatic from additive and dominance variation in generation means II. Heredity 12: 371-390.

Hayman, B.I. and Mather, K. 1955. The separation of genetic interaction in continuous variation. Biometrics II:69-82.

Ingram, W.R. 1958. The lepidopterous stalk borers associated with graminae in Uganda. Bull. Ent. Res. 49:367-383.

Jotwani, M.G. 1982. Factors reducing sorghum yields. In Sorghum in the Eighties: Proceedings of the International Symposium on Sorghum. Patancheru, A.P., India. pp. 251-255.

Jotwani, M.G. and Young, W.R. 1972. Recent developments in chemical control of insect pests of sorghum. In N.G.P. Rao and L.R. House (eds.), Sorghum in the Seventies. Oxford and IBH Publishing Co., New Delhi, India. pp. 377-410.

Kulkarni, N. and Murty, K.N. 1981. Stem borer in sorghum. Indian J. Genet. Pl. Breed. 41:167-169.

Rana, B.S. and Murty, B.R. 1971. Genetic analysis of resistance to stem borer in sorghum. Indian J. Genet. Pl. Breed. 31:521-529.

Seshu Reddy, K.V. 1982. Pest management in sorghum. In Sorghum in the Eighties: Proceedings of the International Symposium on Sorghum, Patancheru, A.P., India. pp. 237-246.

Seshu Reddy, K.V., and Davies, J.C. 1979. Pests of sorghum and pearl millet and their parasites and predators recorded at ICRISAT Center, India, up to August 1979. Cereal Entomology Department Progress Report-2, ICRISAT, Patancheru, A.P., India.

Swindale, L.D. 1982. Foreword. In Sorghum the Eighties: Proceedings of the International Symposium on Sorghum. Patancheru, A.P., India.

Young, W.R. and Teetes, G.L. 1977. Sorghum entomology. An Rev. Ent. 22: 193-218.

PRESENTATIONS OF SOMALIA

D I S C U S S I O N

Axtell

How is sorghum prepared for human consumption in Somalia?

Alahaydoian

Sorghum is prepared in the following ways:

a) Anjera: a thin, pancake type bread similar to the Ethiopian injera but not fermented as much;

b) The pearled and steamed product: usually consumed mixed with pulses such as cowpeas and mung bean;

c) Porridge: in its preparation the sorghum grain is ground and mixed with milk;

d) Thick porridge: this is similar to the Kenya ugali.

Axtell

Are there grain-color preferences for these products?

Alahaydoian

All colors are used but the grain is first decorticated.

Kanyenji

You pointed out that the absence of fertilizer and farm-yard manure in your cultural practices contributes to soil variability which is responsible for the reported high coefficients of variation. Is it that the farmers are not used to application of farmyard manure or is it that it is not available? What is the Ministry of Agriculture doing to encourage the use of manure?

Alahaydoian

Farmers cannot use farmyard manure because it is not easily available in close proximity to the sorghum fields when it is needed. As for chemical fertilizers, not much is available. The government's fixed prices for sorghum grain were previously very low. Now that the prices are deregulated, they have shot up and we are confident that in the near future farmers will have the incentive to use fertilizers. The government is putting up a plant for the production of urea with an initial production of 1,000 tons per year.

Rai

The range of CVs presented in your experiments varied from 50% to 170%. In such a situation, I think it is not statistically valid to say that the grain yield of 229 kg/ha in your entomological experiments is less than the grain yield of 630 kg/ha in your agronomic experiments.

Hussain

The range given was an illustration of the high coefficients of variation we usually encounter. The range for the entomology experiments was mentioned to show that there was a difference in the behaviour of the local sorghums in that section of the field and the yield of the other entries involved in the entomology experiements should be seen in this light.

Rowland

Are the soil differences which result in high CVs related to lack of penetration of water into the soil?

Alahaydoian

Yes, at least partially.

Rowland

Could you break up the soil with a subsoiler or chisel plough, perhaps followed by levelling?

Alahaydoian

We have tried everything, with partial success, but we have no suitable subsoiler.

Omolo

Among the reasons why materials in the entomology experiments were low yielding could have been:

a) Most entomologists select for resistance to insect pests without any consideration of yields and this could be very misleading;

b) The materials you tested could easily have been identified as sources of resistance rather than for agronomic purposes.

It is, therefore, the responsibility of the entomologist and the breeder to cooperate closely if their crop improvement work is to be meaningful.

Alahaydoian

In this case the lines introduced by us have been evaluated primarily for the entomological characters. Later they could be used in the crossing block, but if they are also high yielding they could be used in agronomic trials immediately. That is why we took the yield potential and agronomic characteristics into consideration.

Omolo

ICIPE is already working on the genetic basis of the mechanisms of resistance to Chilo partellus. The information provided in this paper on the type of gene action involved in the inheritance of this parameter is vital for plant breeders because the methodology to be used in any specific breeding program will be determined by knowledge of the type of gene action involved.

SORGHUM RESEARCH IN BURUNDI

Zenon Kabiro*

The three sets of regional trials received from the SAFGRAD/ICRISAT Eastern Africa Program by Burundi in 1983 were low-altitude, intermediate-altitude, and high altitude trials and these were grown at Imbo (830m), Murongwe (1,500), and Munanira (2,100m), respectively. For each ecological zone, the main purpose of these trials was to find varieties superior to those already released in Burundi, i.e. 5DX 160, SVR 8, and SVR 157.

The trials were planted according to the standard directions received from the coordinator of the regional trials. They were planted in randomized complete block design with three replications. The plot sizes were uniformly 5m x 75cm x 5 rows. Sowing in 1983 was done on 15, 19, and 22 December at Munanira, Murongwe, and Imbo, respectively. Thinning was done two weeks after sowing. Data on grain yield, days to flowering, diseases, plant height, and grain color were recorded.

Low-elevation trial

The varieties with the highest grain yields were Urumimbi (3,140kg/ha), 2KX 17/B/1 (2,590), Gambella 1107 (2,200), Sepon 80-1 (2,160), 2KX 17/6 (2,050), Serena (1,980), and Seredo (1,950). The entry 5DX 160 contributed by Burundi to this trial gave 1,660 kg/ha.

Intermediate-elevation trial

Only four varieties looked adapted to Burundi and produced grain yields of 1,000 - 2,000 kg/ha. SVR 8, contributed by Burundi, gave the highest yield of about 2,000 kg/ha. The other three promising varieties were SVR 157, Ikinyaruka, and Susa, all from Rwanda.

---

* Agronomist, ISABU, B.P. 795, Bujumbura, Burundi

High elevation trial

In this set also, the highest yielding and best adapted varieties were those contributed by Rwanda and Burundi. These were SVR 157, an entry from Burundi which produced 4,000 kg/ha, followed by two entries from Rwanda, BM 27 and BM 10, with respective grain yields of 3,280 and 2,000 kg/ha. These trials confirmed that varieties from Rwanda are promising for the ecological conditions of Burundi.

Present and future plans

In the 1984/85 season, the following sorghum trials have been underway: comparison of introduced and local varieties, a grow-out of 30 local collections for evaluation, determining the fertilizer requirements of sorghum.

In 1985/86, the main objective will continue to be identification of superior varieties (from introductions and collections) for the major sorghum ecological zones of Burundi. We will continue our efforts to promote the use of sorghum in diversified food forms in Burundi. Some attention will also be given to the use of sorghum as a forage crop.

SORGHUM RESEARCH IN BURUNDI

D I S C U S S I O N

Kanyenji

I have noted that in Burundi 95% of the sorghum is used for beer. Are there efforts to put sorghum to other uses in Burundi?

Kabiro

A composite flour of sorghum, maize and soybean is being promoted for different foods.

Sehene

The term "beer" covers a variety of home-made drinks with a sorghum base, not necessarily alcoholic drinks. There are, for example, non-alcoholic preparations suitable for children and nursing mothers. There are, of course, fermented drinks which are often taken by men.

SUMMARY OF 1984 SORGHUM WORK IN RWANDA

Celestin Sehene*

INTRODUCTION

The introductions made this year were the regional trials sent to us from the SAFGRAD/ICRISAT Eastern Africa program. We received three sets of trials, one each for lowland, intermediate and highland areas.

Collections

In the 1984 season, we had a severe drought and at some places such as Karama the grain yields for the local collections were negligible. Of all the stations, Rubona was the only one where we were able to harvest grain. This situation again demonstrated the urgent need for early maturing sorghums for our different ecological zones to allow us to cope with the variations in weather conditions.

Varietal yiled trials

Three sets of advanced yield trials were planted at Rubona:

(a) a varietal yield trial composed of Karama material;
(b) a varietal yield trial composed of Rubona materials, and
(c) a regional trial from the SAFGRAD/ICRISAT program.

For the first two trials, the results were very poor due to drought. Only the third trial gave results, as indicated in Table 1.

As shown in Table 1, we got good results with local varieties or those from Burundi. The Ethiopian entry ESIP 12 had a good yield but was very susceptible to leaf blight. The variety 2KX 17 did not germinate at all.

---

*Sorghum Improvement Program Leader in ISAR, Rwerere, B.P. 73, Ruhengeri, Rwanda.

Two varietal trials were planted at Rwerere. The first was made of selections from the existing local collections. Because of drought the results were generally poor. The mean yield for the trial was 2,340 kg/ha, and the best yielding entry gave only 3,056 kg/ha. The second trial planted at Rwerere was the High Elevation Set of the Eastern Africa Cooperative Sorghum Regional Trials. As in the past, only one introduced variety, E1291, along with the local entries, produced seed. Early in the season the introduced varieties had a vigour like maize and later in this season they had little additional growth. The local ones and E1291 looked stunted and thin in the early stages but had a faster growth later in the season.

Two varietal yield trials were planted at Karama. One was composed of local varieties and was being tested for the third time. The drought damaged the trial and the average yield for the trial was 2,635 kg/ha. The highest yielder gave 3,927 kg/ha and the lowest 1,611 kg/ha. The second trial planted at Karama was from SAFGRAD/ICRISAT Eastern Africa. As shown in Table 2 we had very good yields from some of the entries.

Indeed, such materials as Serena and 5 DX160 are early and have very good yields. They have been able to escape the drought at Karama. We have been interested in these varieties and we multiplied them on a large scale in 1985 hoping that in the near future they could be released to farmers.

Table 1. Agronomic data for the Eastern Africa Cooperative Regional Trials, Rubona, 1984

Variety	Plant height (cm)	Days to 50% flowering	Grain yield (kg/ha)
SVR 157 (local)	248	103	4,322
ESIP 12	167	108	3,677
Susa	206	91	3,428
Ikinyaruka	172	82	3,236
SVR 152 (Burundi)	245	103	2,949
SVR 8	161	105	2,796
Buraihi	195	76	2,628
Bakomash 80	203	120	2,315
Mean	200	98	3,169
LSD (0.05)			1,009

Table 2. Agronomic data for the Low Elevation Set of the Eastern Africa Cooperative Sorghum Regional Trials planted at Karama, 1984

Variety	Plant height (cm)	Days to 50% flowering	Grain yield (kg/ha)
5 Dx 160	176	81	5,773
E 525 HT	165	73	5,063
Seredo	151	75	4,998
Serena	160	69	3,980
2KX 17/6	146	77	3,659
Urumimbi	315	104	3,507
Tura	285	105	3,317
Badege	366	106	3,111
Tegemeo	169	74	2,812
Sepon 80-1	159	68	1,932
Tajarib	180	69	1,886
76 T1-23	135	70	1,824
Gambella 1107	171	69	1,799
2KX 17/B/1	170	79	1,745
IS 8595	206	90	1,259
Melkamash 79	161	85	1,075
Mean			2,984
LSD (0.05)			1,815

Agronomic trials

Only one trial involving plant population, weeding frequency, and ridging was planted at Rubona and Rwerere.

Pedigree Selection

The crossing program initiated in 1983 continued in 1984. The F_1 seeds of 1983 were planted in September 1983 and we did not obtain the resulting F_2 seeds in time to plant in January at Rubona and Rwerere in January 1984. Karama was the only place where we planted the F_3 seeds of 1983 and harvested in June 1984. Although there was drought, 109 families were selected and planted in July 1984 under irrigation. We harvested F_4 seeds of 94 selected families in December 84 and planted them in January 1985. The crop was poor and it was difficult to make useful selections.

In April 1984, we made additional crosses. We harvested F_2 seeds in January 1985. The number of F_2s planted in 1985 at Rwerere, Rubona and Karama were 109, 80, 36 respectively.

On-Farm trials

In order to evaluate the response of our advanced materials under farmers' conditions, we planted four varieties in seven farmers' fields at Rwerere. They were planted at a population density of about 150,000 plants/ha by broadcasting and thinning was carried out by the farmers as they saw fit. Although there was drought, we obtained the following results:

(a) There were no significant differences between the two methods of planting. There seemed to be an association between row planting and early weeding.

(b) The varieties BM 10 and BM 27 were selected by all farmers participating in the test.

There were five treatments at Karama, including a local mixture and six participating farmers. We also used two methods of planting and time of weeding. We observed that:

(a) The variety Ngirumpatse was good even under bad weeding conditions;

(b) Where weeding was not done on time, all the varieties gave a better production under broadcasting;

(c) Homogeneity of the plots and the crop preceeding the trials were important. For example, sorghum planted after potato gave twice the yield of plots left fallow for one season.

Seed multiplication

We have been multiplying the following varieties for the locations indicated:

Rubona - WS 1297, SVR 157, Ikinyaruka, Susa
Rwerere - BM 27, BM 1
Kinigi - BM 1, BM 3, N 10.

The effect of plant population and frequency of weeding on grain yield in Rwanda

Sorghum is the most important cereal in Rwanda based on area under cultivation as well as total grain production. It is grown practically everywhere in the country, in different ecological zones, up to 2,500 m altitude or more. To date, local farmers use the broadcasting method for sowing and the final plant population density in the field depends on the farmer's habit and skill in thinning plants. Weeding and ridging are not normally done satisfactorily. The objective of this experiment was to determine the optimum plant density, frequency of weeding and time of ridging.

Under good soil and moisture conditions, the higher plant densities normally give better yields than poor soils with insufficient moisture. The population density has a direct influence on leaf angle, leaf area, plant height, and direct penetration of light in the canopy. Wider inter-rows do not intercept maximum radiation. Eighty per cent of the visible radiation is intercepted by 50% of the total leaf area. Also, 40% of the dry weight in the panicle is due to the contribution of the five top leaves (Rao and House, 1972). Otherwise, the yield increase with increase in plant population is partially due to more efficient use of water and mineral nutrients, and limited water evaporation from the soil or from the plant itself through ranspiration. At a high plant population, it has been found that the leaves become more and more erect and their individual width decreases. In general, yield increases when the plant population increases up to approximately 30 plants/m^2 and starts declining again with increased population. This is applicable to almost all genotypes, but will change with locality (Rao and House, 1972). In Ontario, trials conducted on sorghum hybrids in 1975 showed that an increase of plant population from 75,000 to 300,000 plants/ha increased yield from 4,400 kg/ha to 6,000 kg/ha, whereas an increase from 150,000 to 450,000 plants/ha increased the yield by only 500 kg/ha (Hume and Kebede, 1981). In Ethiopia, plant populations of 100,000 plants/ha (variety ETS 4946) and 160,000 plants/ha (variety Alemaya 70) have been the best ones. In Tanzania, a plant population of 160,000 plants/ha was good in many locations (Brhane Gebrekidan, 1983). In India, 180,000 plants/ha is recommended as optimal where the soil and climate are good. It is reported also that a very high plant population (400,000 plants/ha or more) can produce up to 18 tonnes/ha with some hybrids (Eastin and Wilson, 1982).

In sorghum, the grain yield seems to be positively correlated with plant height, plant population, the number of panicles/unit area, the 1,000 grain weight, and so on. The tillering ability itself is linked with plant population. It decreases when the plant population increases up to appoximately 200,000 plants/ha where it stops for the majority of genotypes. The 1,000 grain weight decreases when the plant population increases to 35 plants/ m^2. In general, it has been observed that there is a decrease in the number of panicles per plant and the number of grains per panicle when the plant population increases. The main problem in plant population trials is to reach and maintain the desired plant population for any meaningful comparison and logical conclusions (Ethiopian Sorghum Improvement Project, 1977).

In general sorghum grain yield is negatively correlated with the quantity of weeds. This influence will be smaller if weeds are controlled mechanically or chemically within four weeks of planting. Many trials conducted in different localities have given similar results on the beginning and the frequency of weedings. At Ilonga, the results from 1981/82 season indicated that two weedings (15 and 30 days after planting) gave good yields with a plant population of 160,000 plants/ha. In Kenya, two weedings are recommended but they have to be done during the first two months after planting (Brhane Gebrekidan, 1983, 1984) (Ethiopian Sorghum Improvement Project, 1977). Weeding by hand 2 and 6 weeks after planting produced results similar to those obtained from a clean culture.

Materials and methods

One trial on plant population combined with frequency of weeding and time of ridging was conducted at three stations (Rubona, Karama, Rwerere). For these locations we used sorghum varieties which have been released to farmers. Due to drought, we did not continue the trial at Rwerere for successive seasons. In Karama, the trial stopped after two seasons because it was difficult to establish differences between treatments with various weeding frequencies. The results reported here concern only the Rubona station. Two varieties, SVR 157 and Ikinyaruka were used. The trial was conducted in a randomized complete block design with 24 treatments and three replications for each variety. Four plant population densities and six frequencies of weeding were chosen. The list of treatments is given in Table 3. The soils at Rubona are of medium fertility. Dates of sowing were the normal ones for the region (mid-January). Row width used was 60cm. We used 10 kg seed/ha and thinned down to the required plant population.

Table 3. Descriptions of the 24 treatment combinations used in the trial

Treatment No.	Treatment combination
1.	Weeding at 1 month + ridging after 2 months
2.	Weeding at 1 month + ridging after 3 months
3.	Weeding at 2 months + ridging after 2 months
4.	Weeding at 2 months + ridging after 3 months
5.	Weeding at 1 & 2 months + ridging after 3 months
6.	Weeding at 1 & 2 months + ridging after 3 months and after flowering.
7.	Weeding at 1 month + ridging after 2 months
8.	Weeding at 1 month + ridging after 3 months
9.	Weeding at 2 months + ridging after 2 months
10.	Weeding at 2 months + ridging after 3 months
11.	Weeding at 1 & 2 months + ridging after 3 months
12.	Weeding at 1 & 2 months + ridging after 3 months and after flowering.
13.	Weeding at 1 month + ridging after 2 months
14.	Weeding at 1 month + ridging after 3 months
15.	Weeding at 2 months + ridging after 2 months
16.	Weeding at 2 months + ridging after 3 months
17.	Weeding at 1 & 2 months + ridging after 3 months
18.	Weeding at 1 & 2 months + ridging after 3 months and after flowering.
19.	Weeding at 1 month + ridging after 2 months
20.	Weeding at 1 month + ridging after 3 months
21.	Weeding at 2 months + ridging after 2 months
22.	Weeding at 2 months + ridging after 3 months
23.	Weeding at 1 & 2 months + ridging after 3 months
24.	Weeding at 1 & 2 months + ridging after 3 months and after flowering.

Results and conclusions

The mean grain yields in kg/ha by treatment combination, variety, and year are given in Table 4. After three seasons of running this trial at Rubona we obtained some results and arrived at the following conclusions:

1. The high population densities led to plants which were weak and slender, especially in the Ikinyaruka variety;

2. Weeding after two months led to too much weed competition and the sorghum plants became chlorotic;

3. Better performances were obtained from treatments with weeding after one month and ridging at two months, or weeding after one and two months with ridging at three months; especially for SVR 157 where the high population densities seemed to inhibit the development of weeds;

4. With 120,000 - 150,000 plants/ha we had good yields with SVR 157, whereas Ikinyaruka produced best at a population of less than 100,000 plants/ha;

5. Thinning after two months was associated with decreased yield;

6. We used a 10 kg/ha seed rate; but in Rubona we established 50 plants/m row and we left 9 plants/m row (150,000 plants/ha) which means that we discarded more than 80% of the seeds after germination. The variety Ikinyaruka produced approximately 60% of the yield of SVR 157. In 1983, they were planted on soils having different levels of fertility, the best being for Ikinyaruka. In 1984, we had a dry season in the beginning and again there was drought at the grain filling stage so yields in general were very low.

Table 4. Grain yield of the plant population, weeding frequency and ridging trial planted at Rubona, 1982 - 1984 (kg/ha)

Expected plant population/ha	Treatment No.	1982		1983		1984		Mean	
		Var.1	Var.2	Var.1	Var.2	Var.1	Var.2	Var.1	Var.2
83,000	1	3704	1881	3318	2176	1930	1358	2984	1805
83,000	2	2722	2041	2971	2817	1710	891	2468	1916
83,000	3	2498	1503	2254	1121	1171	1111	1974	1245
83,000	4	1767	1699	3326	2035	1032	611	2042	1448
83,000	5	3618	2167	2950	2753	1486	1215	2684	2045
83,000	6	3338	2324	3743	2924	1534	1060	2872	2103
150,000	7	3304	2443	3672	3750	2171	1592	3049	2595
150,000	8	4750	2200	2608	3486	1084	1287	2814	2324
150,000	9	3391	1807	3133	2742	1236	1673	2587	2074
150,000	10	2761	1545	2901	2318	1500	1111	2387	1658
150,000	11	4046	3539	3779	4166	1923	1395	3249	3033
150,000	12	4095	2881	2976	4524	1902	1289	2991	2898
183,000	13	4816	2142	2899	4035	2472	1569	3396	2582
183,000	14	4612	2623	4926	4385	1476	1437	3671	2815
183,000	15	3286	1781	2869	3318	1379	1164	2511	2088
183,000	16	3085	1829	2232	3125	951	974	2089	1976
183,000	17	4115	3105	4532	3657	1368	1261	3338	2708
183,000	18	4348	2538	4557	3478	1578	1597	3494	2538
250,000	19	4719	2799	3819	3189	2555	1784	3698	2591
250,000	20	5150	1905	3174	4254	1652	1506	3325	2555
250,000	21	3611	1900	2365	3490	1574	1409	2516	2266
250,000	22	3307	2249	4108	2500	1268	967	2894	1905
250,000	23	4380	3178	3576	5212	1879	1581	3278	3324
250,000	24	3900	3224	3968	3982	2129	1509	3332	2905

Var.1 = SVR 157
Var.2 = Ikinyaruka

REFERENCES

Brhane Gebrekidan. (ed.).(1983. Sorghum Improvement in Eastern Africa: Proceedings of the Second Regional Workshop held in Rubona, Rwanda, 21-25 June 1983.

Brhane Gebrekidan. (ed.). 1984. Sorghum Improvement in Eastern Africa, Proceedings of the Third Regional Workshop held in Morogoro, Tanzania, 5-8 June 1984.

Eastin J.D. and Wilson, G.L. 1982. The plant and its environment, In Sorghum in the Eighties, ICRISAT, Patancheru, India.

Escasinas, A.B. and Escalada, R.G. 1981. Effect of different methods and timing of weed control on the yield components of grain sorghum. SMIC Newsletter No.7, ICRISAT, Patancheru, India.

Ethiopian Sorghum Improvement Project (ESIP). 1977. Progress Report No.5, Nazreth, Ethiopia.

Hume, H.J. and Kebede, Y. 1981. Responses to planting date and population density by early maturing sorghum hybrids in Ontario. SMIC Newsletter No.7, ICRISAT, Patancheru, India.

Rao, N.G.P. and House, L.R. 1972. Sorghum in the Seventies. Oxford & IBH Publishing Co., New Delhi.

SORGHUM RESEARCH IN RWANDA

DISCUSSION

Sehene

In Rwanda the commonest method of threshing is by beating sorghum heads on the ground with heavy sticks. This gives rise to bothersome skin irritation for the persons threshing. I would like to know if there are appropriate threshers for our conditions?

Odongo

Uganda does not have much to offer in thresher technology. However, some equipment which has a rotating drum with beaters and is driven by a bicycle has been tried. A prototype of another kind had been developed at Kabanyolo University Farm but it never took off due to economic problems.

Alahaydoian

In certain places in India, both bullrush millet and sorghum are heaped on the ground and cattle trample over the heaps for threshing. In Lebanon, before the advent of mechanical threshers, a large plank 2m x 1.5m x 10cm had nails with large heads driven into the underside and the plank was attached to some draught power to be pulled round and round over the heaped material. Children like to ride on the plank. After the grain is threshed it is winnowed. This used to be done at the village level and the threshing of the whole village was done on a common threshing floor.

Kirkby

On another issue of post -harvest handling, sorghum dehullers have been developed and marketed in Botswana and their cost is not very high.

Iputo

You reported that the normal sorghum season in Rwanda is December to July. What do sorghum farmers do in such a long season after working in their fields?

Sehene

There are actually two seasons in the country and four other major crops (wheat, peas, beans and potatoes) are grown.

Hussain

Please comment on the annual rainfall in Rwanda for your different altitude zones?

Sehene

Our annual rainfall ranges from about 800 mm in the low-altitude areas such as Karama to 1,200 mm in the highland areas such as Ruhengeri. Rubona, which is our main research station, is intermediate in altitude and has an annual rainfall of 1,110 mm.

Hussain

The variety SVR 157 is used as your local check and yet there is another SVR 157 as an entry from Burundi. Are the two SVR 157 entries from Rwanda and Burundi the same or different?

Sehene

We contributed SVR 157 to the E.A. Cooperative Sorghum Regional Trials. Burundi also contributed SVR 157 which is reportedly doing well in their highland conditions but in Rwanda SVR 157 does well in our intermediate altitude zones. I cannot say if they are the same or not because the variety might have been modified due to growing conditions in Burundi over a number of years.

SORGHUM AND MILLETS RESEARCH IN PDR YEMEN DURING THE 1984 SEASON

Abdul Aziz Ahmed Bawazir*

Sorghum is one of the leading traditional food cereals in PDR Yemen and comprises about 70% of the total cereal production in the country. In the different ecological zones of the country major research efforts are concentrated on the improvement and stabilization of sorghum yields. The El-Kod Agricultural Research Center serves as the headquarters for sorghum research in PDR Yemen. There is also a regional centre located at Seiyun.

Sorghum research in the PDR Yemen during the 1984 season covered a wide range of activities including survey and collection of local germplasm in different ecological zones and breeding and agronomy trials. The weather during 1984 was generally dry. Rainfall for the coastal region taken at El-Kod Meterological Station was only 18mm. Almost all the regions of the country were generally dry with more rainfall received at higher altitudes. Brief comments on the main trials and activities undertaken during the year are given below.

INTRODUCED TRIALS

Local cultivars were included along with entries which were introduced from ACSAD (Syria), ICRISAT (India), and SAFGRAD (Kenya) for evaluation and selection based on grain and forage yield and the adaptability of the introductions to local conditions in the PDR Yemen.

Materials advanced from the ACSAD trials

Fourteen lines were selected and advanced from the three ACSAD observational trials planted at El-Kod during 1983. These selections were sown during July 1984 at El-Kod Agricultural Research Farm where further selections were made. Table 1 presents agronomic data for these selections.

---

* Plant Breeder and Head of Agronomy and Plant Breeding Section, El-Kod Agricultural Research Center, Ministry of Agriculture, Aden, PDR Yemen.

Table 1. Agronomic data for ACSAD selections grown at El-Kod in 1984

Entry	Days to 50% flowering	Plant height (cm)	Head length (cm)	Head Weight (g)	Grain yield (tons/ha)	1000 grain weight (g)	Grain color
Dem.76-70	58	55.3	22.3	51.6	2.06	22.66	Creamy
Dem.76-11	56	110.3	20.3	77.4	3.55	32.66	Creamy
Dem.76-66	54	69.0	22.3	51.7	1.81	21.83	Red
Dem.76-92B	50	104.3	22.3	59.5	2.31	32.50	Red
Dem.78-317	55	230.0	19.7	104.6	3.58	35.66	White
Dem.78-182	57	85.7	21.0	72.7	3.38	27.80	Creamy
Dem.78-284	52	80.3	20.0	51.7	3.31	25.00	Creamy
Dem.78-305	54	276.0	19.7	48.6	2.45	31.00	White
Dem.78-331	55	103.0	19.7	67.6	2.64	26.16	Creamy
Dem.78-321	54	269.7	19.0	58.2	2.79	26.50	White
Dem.77-360	55	297.7	17.7	50.3	2.30	30.33	White
Dem.77-761	56	296.0	20.0	68.4	3.21	28.16	White
Dem.77-950	52	151.0	24.3	66.2	3.02	32.33	Red
Dem.77- 66	56	86.7	24.3	48.9	2.16	22.50	Creamy
Beini (local)	56	254.3	19.3	55.7	1.67	30.16	White
L.S.D. (0.05)	3	47.3	2.9	25.70	-	6.3	
C.V., %	3.3	17.3	8.4	24.7		13	

Grain yield ranged from 3.58 tons/ha for DEM.B78-317 to 1.81 tons/ha for DEM.B76-66. The local check (Beini) gave a grain yield of 1.67 tons/ha. The lines which were early and had high grain yield compared to Beini were selected for further studies next season.

ICRISAT Drought-Resistant Nursery

Thirty-four drought-resistant lines (ISDRON) introduced from ICRISAT during the 1983/84 season were sown in March 1984 at El-Kod for drought evaluation. Twenty-five lines were selected on the basis of grain yield, grain color and general performance. These selected lines were sown in August 1984 at El-Kod.

Table 2 gives agronomic data for these lines as recorded at El-Kod. All the lines outyielded the local check, Beini. The grain yield of the selections ranged from 6.59 tons/ha for DKV-62 to 3.18 tons/ha for DKV-17 as compared to 2.03 tons/ha for the local check, Beini. All the ICRISAT lines had a creamy grain color. The best of these selected lines will be tested again next season under low-rainfall conditions.

SAFGRAD/ICRISAT Regional Trials

The low-elevation and high-elevation 1983 Eastern Africa Cooperative Regional Trials were sown in their respective adaptation zones in the PDR Yemen in 1983. The results of those trials were summarized at last year's Regional Workshop. Varieties Tajarib, Sepon 80, Gambella 1107, and Melkamash-79 were selected for further testing and seed multiplication. Varieties Kadasi, Al-Ganad, ETS-2752 and Alemaya 70 were selected for further testing and seed multiplication at the high-altitude region of the Mukairas Farms.

The mid-altitude regional SAFGRAD/ICRISAT trial was sown in May 1984 at Seiyun. Table 3 presents some agronomic data on this trial. Only four entries headed in this trial. Bird damage was high on emerged heads. ESIP 12 and Bakomash-80 from Ethiopia and 2KX-17 from Uganda gave reasonable grain yields. The grain color in this trial varied from red to dark brown for the introduced entries compared to the preferred white grain color of the local check, Abo-Ali. Though some of these varieties appear to have high yield potential they have undesirable grain color for local use in PDR Yemen. These varieties will be further evaluated for forage use rather than grain, though this situation is not favourable to our farmers who like to select varieties for dual purposes.

SAFGRAD/ICRISAT Katumani lines of 1983

Forty-three lines received from SAFGRAD/ICRISAT Katumani were sown for the first season in an observational nursery. These lines, along with the local check, Beini, were planted at El-Kod in July 1984. Table 4 presents agronomic data for the nursery. As shown on Table 4, the grain yield varied from 8.25 tons/ha recorded in line 678 to 1.99 tons/ha in 557, as compared to 2.82 tons/ha recorded by the local check, Beini. All the introductions had creamy grain color compared to the whitish grain of the local Beini. Days to 50% flowering of the introductions ranged from 81 to 94 days as compared to 86 days for Beini. All the introductions were shorter than Beini. Further selection was made on the basis of earliness and grain yield and the selected lines will be sown in the next season for further evaluation.

Table 2. Agronomic data for ISDRON selections grown at El-Kod in 1984

Entry	Days to 50% flowe-ring	Plant height (cm)	Head length (cm)	Head weight (g)	Grain yield (tons/ha)	1,000 grain weight (g)
DKV-12	68	148	20	118	4.01	26
DKV- 5	67	150	25	122	5.45	24
D-71396	64	131	21	83	3.48	30
DKV-24	68	119	26	132	5.12	31
DKV-19	67	164	26	100	5.51	35
DKV-23	69	134	23	95	5.63	31
DKV- 1	67	148	26	113	5.47	32
DKV- 6	67	130	26	111	5.27	32
DKV-44	69	102	26	121	4.96	30
D-71283	68	140	24	101	4.32	31
DKV-41	65	128	26	53	3.64	28
DKV-25	69	161	25	110	5.98	35
DJ-1195	66	132	22	107	4.79	30
DKV-27	71	132	26	70	3.34	35
DKV-43	66	140	24	88	4.04	33
DKV-13	68	156	24	94	4.19	32
DKV-11	68	146	24	82	3.19	32
DKV-17	67	132	24	78	3.57	29
DKV-53	69	143	28	98	3.18	27
DKV-18	68	171	22	102	4.03	30
DKV-26	67	148	22	146	4.20	22
DKV-62	69	150	22	131	6.59	29
DKV-16	71	151	23	82	6.46	28
D-71395	64	151	23	107	4.59	26
Beini(local)	57	282	20	44	2.63	26
LSD (0.05)	7	33	8	33	1.69	5.7
CV,%	3.4	14	10	8	22	6

Table 3. Agronomic data for mid-altitude trial of the Eastern Africa Cooperative Sorghum Regional Trial grown at Seiyun in 1984

Entry	Days to 50% heading	Plant height, cm	Grain wt, 10 selected heads, g	Grain color
Buraihi	No heading	236	No heading	--
SVR 8	No heading	157	No heading	--
ESIP-12	74	164	294	Red
Bakomash-80	67	171	171	Red
SVR-157	No heading	165	No heading	--
Ikinyaruka	No heading	165	No heading	--
Susa	No heading	187	No heading	--
2KX17	167	133	370	Dark brown
Abo-Ali (local)	53	191	161	White

(a) Bird damage was high;
(b) Aphids and stemborers were selectively severe on the intro duced varieties.

Sudanese introductions

Seventeen varieties from the Sudan, along with the local check, Beini; were planted at El-Kod in an observational nursery in July 1984. Field and laboratory data were recorded. The grain color of the entries was mostly white to creamy. The top yielder with 5.10 tons/ha was M90950. All the Sudanese entries were shorter and later in flowering compared to Beini. They had thick stems and leaves which were regarded as undesirable for forage in PDR Yemen. Some selected entries will be advanced for further testing.

Table 4. Agronomic data for SAFGRAD/ICRISAT Katumani lines grown at El-Kod in 1984

83 SR. Kat No.	Days to to 50% flowering	Plant height (cm)	Head length (cm)	Head weight (g)	Grain yield, (tons/ha)	1,000-grain weight (g)
625	83	158	21	57.8	2.77	23.5
382	90	145	22	58.8	2.85	23.0
368	93	113	23	44.4	2.65	28.0
552	86	144	18	75.4	2.60	23.5
578	87	125	21	60.0	3.68	17.0
386	89	115	18	71.7	4.15	23.5
666	94	138	24	85.4	2.92	30.5
676	85	155	23	70.8	4.93	29.0
388	89	112	18	108.0	2.59	22.5
496	81	120	17	60.0	2.55	26.2
412	88	128	16	62.0	4.44	29.0
511	91	100	23	92.0	5.67	29.0
662	91	104	17	111.4	3.58	27.0
458	85	144	25	74.3	6.63	29.0
505	88	155	23	151.1	6.85	31.0
677	87	138	19	133.3	2.42	23.0
384	86	145	20	58.4	3.99	30.5
462	85	120	19	72.0	5.81	29.5
393	87	188	20	76.6	2.21	23.0
620	86	190	21	95.0	4.82	31.5
696	84	115	19	102.5	6.52	23.0
372	85	110	24	55.0	1.99	28.0
668	86	150	24	110.0	4.05	32.0
557	88	112	26	216.6	3.07	19.5
370	88	128	22	52.5	3.23	30.0
570	86	130	19	65.0	3.07	23.0
504	91	100	21	65.0	3.23	35.0
554	89	115	23	102.9	5.51	23.0
457	91	143	25	120.9	6.26	27.0
365	86	160	24	113.3	5.00	25.0

Table 4 (Contd)

83 SR. Kat No.	Days to 50% flowe-ing	Plantt height (cm)	Head length (cm)	Head weight (g)	Grain yield (tons/ha)	1000 grain weight
467	85	118	19	54.6	2.82	24.0
1,056	89	138	19	44.4	2.61	25.0
586	89	115	21	66.8	3.55	29.0
456	83	133	20	70.0	3.59	26.5
486	84	98	22	58.7	2.66	24.5
655	85	118	17	55.0	2.43	23.0
371	89	115	23	94.2	5.00	26.0
367	89	185	30	116.6	6.01	27.0
533	89	115	21	56.0	3.13	26.0
678	88	155	22	172.5	8.25	35.0
628	89	100	16	57.5	2.96	24.0
369	89	120	21	100.0	4.64	31.0
558	85	86	19	73.4	4.90	25.0
Beini(local)	86	300	20	50.0	2.82	30.0

Table 5. Agronomic data for four pearl millet entries grown at El-Kod in 1984

Entry	Days to 50% flo-wering	Plant height (cm)	Head length, (cm)	Head weight (g)	Grain yield (tons/ha)	1,000-grain weight(g)
SSC-K7	47	167	28	38	3.11	9.6
WC-C75	46	156	26	29	2.37	8.3
Tihama-1	50	178	27	38	2.70	8.3
Dukhun Baladi	56	161	28	33	2.03	5.7

HERBICIDE TRIALS

It was generally observed for the last three seasons (1980-1983) that sorghum treated with the two chemical herbicides (propachlor and atrazine) had significantly out-yielded controls (no weeding). It was also concluded that a combination of propachlor and atrazine in the ratio of 3:0.5 out-yielded all other treatments tested including 2, 4-D and hand weeding. The use of a propachlor and atrazine combination will be demonstrated in large-scale farm production at El-Kod and extension farms this year.

OTHER ACTIVITIES

Collection of sorghum germplasm

In 1984, sorghum collection in the PDR Yemen took place in the coastal, mid- and high-altitude areas where 40 sites were sampled. Sixty-one local collections from 1983 were sown at El-Kod. Further detailed study and evaluation of this material will be undertaken through the IBBGR project which it is proposed will be implemented in 1986.

Pearl-millet introductions

Three introduced varieties of millet, SSC-7, WC-C75, Tihama-1 and the local check, Dukhan Baladi, were sown in July 1984 in observation plots at El-Kod. Table 5 gives agronomic data for these entries as recorded at El-Kod. All the introduced varieties were significantly earlier in flowering than the higher yielding local check. SSC-K-7, Tihama-1, WC-C75, and the local check yielded 3.11, 2.70, 2.37, and 2.03 tons/ha, respectively.

COMMENTS ON PLANS FOR THE NEXT SEASON

1. We will continue to evaluate the selections from the ACSAD, ICRISAT and SAFGRAD trials.

2. We are planning to concentrate more on the collection, conservation and utilization of our local germplasm.

3. Large-scale verification of the chemical herbicides (propachlor and atrazine) will be carried out on demonstration and extension farms in the country.

4. Collection of the local germplasm of pearl millets will be initiated and further trials on the introduced ones will be continued.

SORGHUM AND MILLETS RESEARCH IN PDR YEMEN

DISCUSSION

Akol

How important is sorghum in the PDR Yemen?

Bawazir

It comprises about 70% of total cereal production in the country.

Oyiki

Goose-neck types of sorghum are said to be receiving less bird damage than their upright counterparts. What is the experience in the PDR Yemen?

Bawazir

We have goose-necked types also. Although the character is associated with less bird damage, the Yemen sparrows have become used to feeding easily on these types. The damage on these types is, however, less severe in comparison to upright types of heads.

PROBLEMS AND METHODS IN PEARL MILLET BREEDING

K.N. Rai and J.R. Witcombe*

Pearl millet (Pennisetum americanum (L.) Leak, is grown on an estimated 26 million ha annually, principally in the arid and semi-arid tropical regions of the Indian subcontinent and Africa. It is largely cultivated by small farmers with limited economic means and is an important crop of subsistence agriculture. The growing environment of this crop is characterized by (1) intermittent and occasionally prolonged moisture stress caused by inadequate and erratic rainfall and high temperatures, (2) marginal soils with poor fertility; scanty natural vegetation and poor water-holding capacity, and (3) the occurrence of numerous diseases, insect pests and, sometimes, parasitism by witchweed (Striga). All these factors cause substantial grain yield losses, with yield averages around 500 kg/ha in the Indian subcontinent and 600 kg/ha in Africa (FAO, 1978). Sub-optimal management, caused by the poor resources of the farmer and often by lack of overall agricultural planning at the government level, adds yet another constraint to productivity.

The immediate breeding objective should be an attempt to stabilize grain yields at slightly higher levels, say between 900 and 1200 kg/ha. However, the long-term plan must include stepping up the productivity of the crop considerably if the continually growing demand for food is to be met. This will only be possible by improved agricultural technology in which input-responsive varieties and improved cultural practices are vital components.

The priority that a character receives in a breeding program is determined by its overall contribution to grain yield and quality, its genetic resources and the ease of its genetic manipulation affected by heritability, linkage and pleiotropy. The primary role of a program and the type of products to be bred (hybrids, open-pollinated varieties) greatly influence the choice of an appropriate breeding methodology. The purpose of this paper is to briefly review the problems that lead to low, unstable grain yields, and then to present an account of breeding methods used to develop high yielding materials, drawing heavily on the work done at ICRISAT Center.

*Pearl Millet Improvement Program, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru P.O., Andhra Pradesh 502 324, India

Biotic problems

Besides crop architecture presenting a low-yielding framework, several disease and insect pests, birds, and a parasitic weed (Striga) directly affect the host plants and cause grain yield losses. The hybridization of the crop with a wild relative, P. violaceum, produces shibras which have poor productivity and these can form a significant proportion of the crop and cause substantial losses. There exists considerable variation in the distribution of these biotic factors, and in the frequency and intensity of their occurrence. Hence, the economic importance of these factors varies greatly between countries and regions.

Crop architecture

The traditional African cultivars are tall ('Gero' or 'Souna', 1.5-3m, and 'Maiwa' or 'Sanio', 3-6m), generally have thick stems and are too leafy. One of the major obstacles in obtaining high grain yield of pearl millet is that the millet now cultivated in Africa has a morpho-physiological behaviour more similar to grass used for forage than that of a cereal destined to produce grain (Bilquez, 1975). This crop has an impressive capacity to produce dry matter as compared to maize and sorghum but a large proportion of this dry matter goes to stem and leaves, reducing the harvest index to 15-20 %, which is much lower than the percentages typically found in maize and rice (Bilquez, 1975). The harvest index of traditional Indian cultivars is not much higher than the traditional African cultivars. Improved varieties, on the average, have about a 50 % higher harvest index than the traditional ones (Bramel-Cox, unpublished), although still much below those for maize, sorghum, wheat and rice. The excessive height of many varieties increases the risk of lodging and grain loss after storms. Tall, late-maturing varieties with a low harvest index do not respond sufficiently to better management inputs to give much higher returns and hence they are less suitable for improved and intensive agriculture.

Diseases

More than 50 diseases of pearl millet have been reported (Ramakrishnan, 1971; Ferraris, 1973) but only four are of any economic significance. These are downy mildew (Sclerospora graminicola (Sacc.) Schroet., ergot (Claviceps fusiformis, Loveless), smut (Tolyposporium penicillariae Bref.) and rust (Puccinia penniseti, Zimm.).

Downy mildew

Downy mildew is the most serious of all the pearl millet diseases. It is endemic on landrace cultivars and occurs all over the major millet growing areas in the world. However, its incidence on the state and regional level rarely exceeds 15% (Andrews *et al.*, 1984). Under traditional agricultural systems where numerous landraces greatly diversify the genetic base, both between and within populations, the threat of downy mildew is naturally checked at a low level. The large-scale adoption of high-yielding cultivars upsets the natural host-pathogen balance. This risk, however, is assumed to be less serious with more variable open-pollinated varieties than with uniform hybrids.

The first downy-mildew epidemics on pearl millet occurred in India in 1971 when hybrids based on a susceptible male-sterile line, Tift 23A, originating from Georgia, USA, came into prominence (Safeeulla, 1977). In the years that followed several downy-mildew-resistant male-sterile lines were developed but the hybrids on one of them (5141A) accounted for more than 70% of the area under high-yielding pearl millet varieties. In 1983 male-sterile line 5141A and its hybrids succumbed to downy- mildew epidemics again, thus resulting in the decision to withdraw 5141A and its hybrids from further commercial utilization.

Ergot

Ergot generally occurs in a much less severe form than downy mildew in almost all the pearl millet growing countries but is particularly common in Zambia, Senegal, Nigeria, Tanzania, and India (Sundaram, 1975). Ergot does occasionally assume epidemic proportions. In 1957 it is reported to have appeared in the epidemic form in a number of pearl-millet growing areas in the Maharashtra State of India, and the incidence ranged from 25%-100% in the worst affected fields. Wet weather conditions during flowering, resulting in high relative humidity and low night temperatures, are highly favourable for ergot infection (Thakur *et al.*, 1982). On a national basis, the direct yield losses due to ergot may not be very high, but it adversely affects the grain quality by contaminating it with toxic alkaloid-containing sclerotia of the pathogen, hence making it unfit for human and animal consumption (Krishnamachari and Bhat, 1976). It is generally observed that F_1 hybrids are more susceptible to ergot than open-pollinated varieties. Research at ICRISAT has shown that the availability of pollen from early flowering plants in a heterogeneous open-pollinated population provides an escape mechanism from ergot (Thakur and Williams, 1980; *et al.*, 1983a).

The conidia of *C. fusiformis* take 16 hours to germinate as compared with 1 hour for pollen, and shortly after pollination the flower is no longer susceptible to infection. The mechanism may be lacking in F_1 hybrids which are generally uniform in time of flowering.

Smut

Smut is still less widespread and less serious as compared to downy mildew and ergot. It occasionally occurs in areas characterized by high day temperatures and high relative humidity. At times, it can cause serious yield losses but generally in localized pockets. Its occurrence is particularly pronounced in Senegal, Burkina Faso, and Mali in West Africa and in northern and north-western parts of India (Rachie and Majmudar, 1980).

Rust

Pearl-millet rust is a disease of minor economic importance. It is known to occur in all areas where the crop is grown, particularly in southern India, and southern, central and eastern Africa (Rachie and Majmudar, 1980). There are no published reports on the extent of grain yield losses caused by this disease, although occasional outbreaks may lead to severe losses in grain yield and fodder quality (Wells *et al.*, 1973). In the rainy season planting in India, rust generally occurs after anthesis resulting in little or no loss in grain yield, although it causes a substantial loss in fodder quality. Rust is more frequent on the late planted crop in the rainy season in the central/southern parts of India.

Pests and parasites

A host of pests (insects, birds), a parasitic weed (*Striga* spp.) and a weedy relative of pearl millet (shibra) are yield-reducing biological factors. All these are of much more economic significance in Africa than in India. Out of nearly 100 species attacking pearl millet, the only regular pests in West Africa, for instance, are stem borers (*Acigona ignefusalis* Hmps, and *Sesamia* spp.) and earhead caterpillars (*Masalia* spp., *Raghuva* spp.) (Gahukar, 1984). Short duration 'Gero' or 'Souna' millets are particularly susceptible to *Raghuva* and *Masalia* attacks. Sporadic pests such as hairy caterpillars (*Amsacta moloneyi* Druce), armyworms (*Spodoptera* spp. and *Mythimna* spp.) and grasshoppers (Acrididae) may cause considerable losses to crops during prolonged droughts early in the season. Coutin and

Harris (1968) reported that millet grain midge (*Geromyia penniseti*., Felt) is very widely distributed in the savannah zones of West Africa, and has the potential of turning into a serious pest of pearl millet. The grain midge has caused 5-50% damage in 1975 screening trials in India. However, the more serious pests in India, though of endemic importance, are white grubs (*Holotrichia* spp.) in the lighter soils of Rajasthan, and shootfly (*Atherigona approximata*) in parts of Tamil Nadu and Gujerat in India (Verma, 1980). Gram pod borer (*Heliothis armigera*) is becoming a serious pest of pearl millet in Rajasthan in India.

Most of the work on insect pests of pearl millet deals with various aspects of their biology, ecology and taxonomy. Very little work has been done on developing field-screening techniques and identifying sources of genetic resistance in hosts which can be utilized in genetic improvement of insect-pest resistance.

Witchweed is a very serious problem in several millet growng regions of the world and can, at times, result in total crop failure. There are two major species of *Striga* which are of economic importance: (1) *Striga asiatica* which is a self-pollinating species and is widespread in the semi-arid regions of India, particularly Gujerat, Rajasthan and parts of Andhra Pradesh; it is also widespread in southern Africa (from the Lake Victoria basin in Tanzania to South Africa), (2) *Striga hermonthica* which is a cross-pollinating species and is widespread in the semi-arid zones of northern tropical Africa from latitudes 5^0S to 20^0N (Ramaiah *et al*., 1983)

Abiotic problems

The major abiotic factors limiting pearl-millet production include moisture stress, low fertility and sub-optional management. Whereas the latter is associated with the limited economic means of farmers, the other factors relate to the natural environments where pearl millet is cultivated.

Moisture stress

Almost entirely a rainfed crop, pearl millet is grown in areas of 200-800mm of rainfall/year (Bidinger *et al*., 1983). When grown rainfed in the areas with low and erratic rainfall and in soils with low water-holding capacity, the crop experiences moisture stress which reduces grain yield. Eight high-yielding hybrids were studied under rainfed and irrigated conditions in the All India Coordinated Pearl Millet Trials (Harinarayana, 1977).

Irrigation had substantial positive effects on grain yield. The record high yield of 8.03 million tonnes in 1970/71 in India was ascribed largely to a favourable monsoon, and the steep decline to 3.93 million tonnes in 1972/73 was ascribed largely to an unfavourable monsoon. The unfavourable monsoon not only led to the decline in yield per hectare but it also caused the decline in total area planted to pearl millet (11.81 million ha in 1972/73, against 12.91 million ha in 1970/71).

Poor Plant Stand

Under farmers' field conditions the establishment of an unsatisfactory plant stand can be a serious problem affecting pearl-millet productivity. This may be due to poor seed quality and consequent unsatisfactory germination, early seedling death caused by downy mildew, moisture stress, intense weed competition, and sand blast or soil covering in sandy soils. A major reason for poor plant stand in most of the non-sandy millet growing areas is the failure of seedlings to emerge through the crusted soil surface. Field-screening techniques for selecting millet (and sorghum) genotypes with increased ability to emerge through the crusted soil surface have been developed (Soman et al., 1984). Further studies (Soman et al., 1985) have shown that genotypic differences in millet exist for ability to emerge through crusting and that these differences are repeatable over trials and over different seed lots and hence they are heritable.

Seedlings with high vigour would tend to have competitive advantages against weeds; vigorous seedlings would also resist better the danger of getting covered with wind-blown soils. Research has shown (Bidinger et al., 1985) that visual selection scores for seedling vigour were significantly correlated with actually measured seedling vigour criteria and the seedling vigour is a heritable trait. It is possible to combine seedling vigour with other agronomically desirable traits and yield potential.

Low fertility

Nitrogen is the major soil-fertility factor limiting production in the semi-arid tropics. Although about 60 kg/ha of applied N has been shown to be the most economical level, and at times up to 80 kg N/ha has proved economical (Gautam, 1982), often farmers' resources would not permit substantial nitrogen applica -

tion at the current productivity levels of the crops and under prevailing farming systems. Estimates of nitrogen fixation associated with pearl millet, based on acetylene reduction essays, N balance studies in pots and ^{15}N isotope dilution techniques, have indicated that 15-20 kg/ha of nitrogen is fixed through biological nitrogen fixation (Wani, 1984). Inoculations with N_2-fixing bacterial i.e.,Azospirillum lipoferum and Azotobacter chroococcum (Wani at al., 1985) and Azospirillum brasilense (Subba Rao, 1984) have resulted in increased grain yield and enhanced nitrogen uptake upto 34 kg/ha in pearl millet.

Studies have also shown that there is substantial variation in bacterial populations for enhancing the associative nitrogen fixation, and substantial variation in millet genotypes for their associative nitrogen fixation (Wani et al., 1985). There is also significant interaction between bacterial cultures and host genotypes for nitrogen fixation. Investigations have been started to evaluate the effectiveness of selection for increased associative nitrogen fixation.

GENETIC IMPROVEMENT

Setting priorities

Breeding varieties to stabilize pearl-millet grain yields at higher levels in a low-input agricultural system is a formidable challenge. However, pearl millet is still a poorly researched crop and the magnitude of genetic diversity available for the improvement of this crop is immense. Considering the mechanics of seed production and the level of agricultural development in most of the millet growing countries, improved genotypes will often be open-pollinated varieties and not hybrids. However, novel plant types with a very high yield potential under improved environments could provide the impetus for improvement in farming systems and make high-input-based millet cultivation an attractive proposition. Such millets could replace crops such as sorghum and maize in areas where they are not very productive. The best genotypes for such situations would be hybrids.

Factors which need to be taken into account for developing criteria as to which characters need to be emphasized in a genetic improvement program include: (1) the overall effect of the character on productivity, (2) the resources available for the improvement of that character, and (3) the nature and knowledge of the genetic control of the character. Thus, drought is the major yield reducer and breeding for drought-resistance should, in principle, receive highest priority. In practice, however, the situation is altogether different as adequate facilities for drought resistance breeding are practically non-existent in almost all of the breeding programs. ICRISAT has developed facilities and has staff to screen for drought resistance. Three problems, however, remain:

1. The intensity of drought and the period to which it extends varies. Consequently it is extremely difficult to breed a genotype adapted to all possible drought environments;

2. The heritability of drought resistance is low and the nature of genetic variability is not yet understood;

3. Selection under field conditions is difficult because of the problems of producing a precise drought environment and a laboratory method which corresponds with the field test is not known.

The above factors have meant that our breeding efforts depend more on screening under drought conditions the high-yielding varieties and hybrids that have been bred under non-stress conditions.

In breeding for disease resistance, the highest priority has been given to downy mildew because globally it is the most serious disease problem and diverse source of resistance to downy mildew are available in breeding materials and in genetic resources collections. Selection for this disease is relatively simple and effective large-scale field-screening techniques are available.

Smut receives slightly higher priority than ergot in the ICRISAT program if only because the inheritance of smut is less complex, and diverse sources of smut resistance are available from more agronomically acceptable backgrounds.

Striga is a very serious problem in most of the West African countries. The lack of adequate funding has led to little research on the development of an effective field-screening technique and on the search for sources of resistance.

The bulk of research on insect pests has been done in West Africa where they are a major problem. Most of this research, however, relates to biology, ecology and taxonomy of the pests and not much has been done to develop effective screening techniques and find sources of resistance. Successful breeding for resistance to bird damage is unlikely and other methods should be resorted to (e.g. biological control).

Genetic resources

The Genetic Resources Unit (GRU) at ICRISAT has a world collection of over 17,000 accessions of pearl millet (including wild and weedy forms) which represent a wealth of genetic variation for numerous traits (Table 1). Collections from India represent a narrow subset of the total diversity in the pearl millet gene pool. African collections have useful plant character- ristics, e.g. higher head volume, large seeds, disease resistance, and high protein content.

African collections have proved more useful to Indian breeding programs (mostly in hybridization) than vice versa. Some of the germplasm from African collections has been directly adopted with mild selection: (1) from the first cycle of recurrent selection at ICRISAT Center in the World Composite, which was developed at Samaru in Nigeria, an open-pollinated variety, WC-C75, was bred; after five years of testing in the All India Coordinated Millets Improvement Project (AICMIP) trials it was released for general cultivation in India, (2) Serere 10LA and Serere 10LB, bred at Serere Research Station in Uganda, were introduced by ICRISAT. Further selection in this material by MAHYCO (a private seed company in the Maharashtra State of India) led to the development of a hybrid which has become very popular in India, (3) Selection in some early-maturing large-seeded materials of Togo origin has produced open-pollinated varieties which have performed very well, in the International Pearl Millet Adaptation Trial (IPMAT) (Table 2).

Some of the dwarf populations, particularly 3/4 Ex Bornu and 3/4 Hainei-Kirei, bred by IRAT (Chantereau and Etasse, 1976) have found extensive usage in the breeding programs at ICRISAT. Several breeding lines and populations of African origin, such as the Nigerian Composite, Ex Bornu, and the 700,000 series lines from Nigeria have also found extensive usage in millet programs at ICRISAT Center. A large number of breeding lines, populations, and accessions from African sources have been used in crosses with materials from Indian breeding programs to develop composites, synthetics and hybrid parents. The knowledge gained from our genetic resources utilization program shows that materials available from African breeding programs have been more useful in crosses with the breeding materials developed in India than the landrace materials. A diverse array of materials developed from Indian x African crosses and from population improvement programs have been extensively supplied to Indian millet programs and overseas.

Table 1. Range of variation in pearl millet: Rainy season evaluation, ICRISAT Center

Character	Range
1. Time to 50% bloom (days)	33-140
2. Plant height (cm)	35-475
3. Tillering number	1-210
4. Stem thickness (mm)	2.8-15.0
5. Leaf number	6-25
6. Leaf length (cm)	25-120
7. Leaf width (mm)	11-78
8. Head length (cm)	5-165
9. Head thickness (mm)	11-64.5
10. Bristle length (mm)	2-60
11. Grain no./head	379-3337
12. 1,000 grain mass (g)	2.54-19.32
13. Grain color	White - dark purple

Source: S. Appa Rao, unpublished.

Table 2. Performance of some promising varieties in the International Pearl Millet Adaptation Trial (1984)

Variety	Origin	Grain yield[1] (t ha^{-1})	Smut severity[2] (%)
ICMV 82132	Smut resistant composite	1.88	4.0
ICTP 8202	Togo populations	1.83	-
ICTP 8203	Togo populations	1.81	-
ICMS 8283	Synthetic	1.74	1.0
WC-C75 (Check)	World Composite	1.68	13.0

1. Based on 18 locations.

2. Based on four locations in India (inoculated heads).

Resistance screening

Downy mildew

The development of an effective and large-scale field screening technique at ICRISAT (Williams et al., 1981) formed the basis of success in breeding for downy-mildew resistance. The key elements involved in this technique are the utilization of highly susceptible materials to provide the site for rapid and uninhibited sporangial production, and the provision of a mist (perfo spray) irrigation system to develop high humidity, a necessity for massive sporangia production and infection. This technique was applied to develop a downy-mildew disease nursery at ICRISAT and about 10 ha of breeding materials and varieties/hybrids under test are passed through it annually. This has resulted in the development of breeding lines and varieties which have exhibited very high levels of resistance to downy-mildew pathogen populations in India. A large proportion of these resistant materials, however, have registered high downy mildew incidence in West African locations. Studies have shown that West African isolates, particularly those from Niger, Nigeria and Burkina Faso, are more virulent than those from India (Ball and Pike, 1984). An International Pearl Millet Downy Mildew Nursery (IPMDMN) testing program, organized by pathologists at ICRISAT, has led to the identification of several selections from accessions which have exhibited very high levels of stable downy-mildew resistance across several locations in India and at some locations in Africa over several years of testing (Table 3). This testing program has shown that West African germplasm serves as a rich source of stable downy-mildew resistance.

Ergot

An effective large-scale field-screening technique for ergot resistance has been developed (Thakur et al., 1982) and is being used extensively. The technique involves the spraying of macroconidial water suspension (macroconidia obtained from the honey-dew of infected inflorescences) on the fully emerged stigma, protected from contamination with foreign pollen and the maintenance of high humidity by running overhead sprinkler irrigation twice daily during the period of inoculation to early grain filling.

Table 3. Breeding lines with high levels of stable downy-mildew resistances.

Line (origin)	Test year	Mean severity (%) Indian locations: Jamnager	ICRISAT	Mysore	West African Locations: Kamboinse	Samaru	Kano
SDN 503 [Nigeria]	1979	1	2	2	2	17	4
	80	2	2	14	2	13	9
	81	2	3	53	4	13	22
	82	14	18	15	21	–	
	83	0	1	3	–	1	5
P-7 [Mali]	1979	0	<1	0	7	17	13
	80	2	<1	9	0	19	24
	81	0	1	5	1	48	16
	82	0	20	4	22	–	–
	83	0	0	4	–	19	14
700251 [Nigeria]	1979	0	<1	3	5	15	23
	80	2	<1	2	1	15	30
	81	0	0	13	2	33	19
	82	3	14	5	35	–	–
	83	0	0	2	–	14	19
700516 [Nigeria]	1979	0	0	0	6	20	26
	80	1	<1	3	1	20	17
	81	0	0	9	3	32	21
	82	2	4	7	10	–	–
	83	1	1	4	–	13	15
700651 [Nigeria]	1979	0	<1	0	3	39	16
	80	0	0	5	1	25	30
	81	0	2	1	1	29	47
	82	1	4	10	18	–	–
	83	0	1	8	–	12	18
7042 (Chad)	1979	70	91	30	74	–	–
	80	70	58	60	73	98	98
	81	67	72	57	69	100	96
	82	56	79	47	87	–	–
	83	49	78	61	–	99	100

a Susceptible check.

Source: S.X. Singh, unpublished.

An extensive screening of more than 4,000 accessions from the ICRISAT GRU showed that no line was highly resistant to ergot (Thakur et al., 1982). Intermating among the ergot low-susceptibility parental lines (ergot severity mostly 20-40%) and selection for resistance in the segregating generations, however, was successful in producing several F_6 progenies which had less than 1% ergot under artificial inoculation. Multilocational tests of these lines at six locations in India and at Samaru in Nigeria over a 2-3 year period showed these lines as having generally less than 1% and rarely more than 5% ergot (Table 4). The distribution of resistant/susceptible progenies at various stages of inbreeding and the slow rate of resistance build -up is indicative of ergot resistance being controlled by polygenic recessives. Genetic studies conducted later have provided the evidence for this view (Thakur et al., 1983c). All the ergot resistant lines have short protogyny. After pollination the floret is no longer susceptible and pollen germinates much more rapidly than conidia (Thakur and Williams, 1980). Tests have shown that almost all of the ergot-resistant lines possess very high levels of resistance to downy mildew and smut as well.

Smut

Bagging millet heads under natural smut pressure at hot-spot locations generally gives good screening for resistance. The development of an effective, large-scale field-screening technique at ICRISAT Center has considerably increased the precision of screening (Thakur et al., 1983b). The technique involves the insertion of sporidial water suspension (sporidia produced on carrot/potato agar) with a hand-held injection into the flag leaf sheath at the boot stage. The humidity control is exercised in the same way as in the case of ergot screening. The application of this technique has led to the development of several smut-resistant lines (Table 5). Very much like ergot, there are indications that smut resistance is also controlled by polygenic recessives. But, unlike ergot, the inheritance appears less complex; this is evident from much faster progress made with the breeding of smut-resistant sources as compared to ergot-resistant sources. Also, unlike ergot, high levels of smut resistance are available in much more diverse and agronomically acceptable backgrounds. A large number of smut-resistant lines have also exhibited very high levels of downy-mildew resistance.

Rust

A modest beginning has recently been made at ICRISAT to screen accessions for diverse sources of rust resistance. At present, the screening is done by late planting at "hot-spot" locations in southern India. Several accessions with very high levels of rust resistance have been identified. Of immediate interest, however, is an S_5 progeny selected from accession IP 2696 collected from the Republic of Chad which carries a single dominant gene for rust resistance (Andrews et al., 1985).

Table 4. Performance of ergot-resistant entries at Samaru (Nigeria) and six Indian locations (1981-1983).

Entry[1]	Ergot severity (%)[2]						
	Samaru	Aurangabad	ICR/Center	Jamnager	Ludhiana	New Delhi	Mysore
	1982/83	1982/83	1982/1983	1981/83	1981/83	1981/83	1982/83
ICMPE 134-6-9	<1	<1-1	<1	0-<1	<1-5	0-2	<1
ICMPE 134-6-11	<1-1	<1-5	<1-1	<1	<1-2	0-2	0-<1
ICMPE 134-6-41	<1-1	<1-5	<1-1	<1	<1-1	<1-2	0-<1
ICMPE 134-6-34	<1-1	1-2	<1-1	<1-1	<1-5	<1-2	0-<1
ICMPE 134-6-25	<1-1	1	<1	0-<1	<1-3	<1-1	0-2
ICMPE 13-6-27	<1-6	1-2	1-5	1-7	2-5	<1-5	0-3
ICMPE 13-6-30	1	1	2-3	<1-4	<1-8	2-4	1
ICMPES 1	0-1	1	1-2	1-2	1-3	1	1
ICMPES 2	<1-1	1	1-2	0-<1	<1-2	0-3	<1
ICMPES 23	0-1	1-2	0-3	0-1	2-5	<1-2	0-1
ICMPES 27	0-<1	1	<1-1	0-<1	<1-2	<1-1	0-3
ICMPES 28	<1	2-3	1-7	<1-1	<1-2	2-3	0-1
ICMPES 32	1	4-16	1-2	<1-2	1-2	<1-1	1
Susceptible (Control)	83-89	91-97	90-98	44-58	65-66	23-52	33-62

1. ICMPE(S) = ICRISAT Millet Pathology Ergot-Resistant Line (Sib-bulk).

2. Based on 20-40 inoculated inflorescences/entry in two replications.

<u>Source</u>: ICRISAT 1983

Table 5. Smut severity (%) of the best smut-resistant pearl millet evaluated at three locations in India and four locations in West Africa

Entry	Indian locations						West African locations							
	Hissar		Jamnagar		ICRISAT Center		Bambey		Samaru		Kamboinse		Sadore	
	1982	1983	1982	1983	1982	1983	1982	1983	1981	1983	1979	1982	1981	1983
SSCFS 252-2-4	0	0	0	0	0	0	1	2	4	19	0	0	0	<1
ICI 7577-S-1	<1	0	0	0	<1	0	<1	1	3	2	0	<1	4	<1
EB 132-2-S-5-2-DM-1	<1	0	0	0	<1	0	1	1	6	12	1	1	1	<1
EBS 46-1-2-S-2	0	0	<1	0	<1	0	–	1	4	6	–	1	1	0
EBS 112-1-S-1-1	<1	0	0	0	0	0	3	1	1	–	<1	1	<1	<1
P 489-S-3	0	<1	<1	0	0	0	2	2	1	1	–	<1	<1	<1
ICMPS 101-1	0	0	<1	0	0	0	<1	1	–	3	–	–	–	<1
ICMPS 904-3	0	0	<1	0	0	0	<1	1	–	5	–	–	–	0
ICMPS 1600-4	<1	<1	0	0	0	0	2	1	–	8	–	–	–	<1
ICMS 2001-2	<1	<1	<1	0	<1	0	<1	1	–	7	–	–	–	6
Susceptible [Control]	36	78	58	44	72	82	24	54	51	32	67	43	28	47

1. Mean severity based on 20-40 inoculated/bagged heads in two replications.

Source: ICRISAT, 1983.

BREEDING METHODS

Recurrent selection

Recurrent selection, also known as population improvement, population breeding and composite breeding, has been effectively applied to the genetic improvement of cross-pollinated crops (Allard, 1960; Hallauer and Miranda, 1981). Various forms of recurrent selection, i.e. mass selection (simple mass selection, gridded mass selection, recurrent restricted phenotypic selection), and full-sib, half-sib, S_1 and S_2 progeny selection have been used in population improvement at ICRISAT (Singh et al., 1985). Since different methods or combinations of them have been applied on different composites (Fig. 1), their efficiencies cannot be precisely compared. It appears as if no method is superior to the other and all methods involving progeny testing have yielded positive and perhaps similar results, leading to improvement in grain yield in almost all the composites. On a per-cycle basis and averaged over 2-5 cycles, grain yield gains of 1.8-5.0% per cycle have been recorded (Table 6) which is similar to those observed for maize (Hallauer and Miranda, 1981). These gains in grain yield have been achieved with marginal improvement for downy mildew resistance, earliness and shorter plant height. Detailed studies in a medium maturity composite showed that, after two cycles of full-sib selection, there had been no decline in genetic variability (Singh et al., 1985). This result may perhaps be applicable to other composites as well.

Several factors have been responsible for the above successes. One such factor is multilocational testing. Generally, 300-400 progenies are yield tested twice at two to three locations. Based on the average performance across the locations, 50-70 top ranking progenies are recombined into the next cycle (Fig. 2). Another factor has been the use of visual scores which not only take into account the yield potential of the progenies but also their overall acceptability (straw strength, plant height, maturity, grain size, head compactness, exsertion and tillering).

Three cycles of S_2 selection and six cycles of gridded mass selection, restricted recurrent phenotypic selection and full-sib selection applied on the World Composite, with a single location test and without visual scoring, resulted in much lower genetic gains than ordinarily obtained in other composites with multilocational tests and visual selection (Singh et al., 1985). The same experiment also revealed that there were no significant differences among various selection methods, a conclusion reached for maize which has been much more extensively researched than any other cross-pollinated crop.

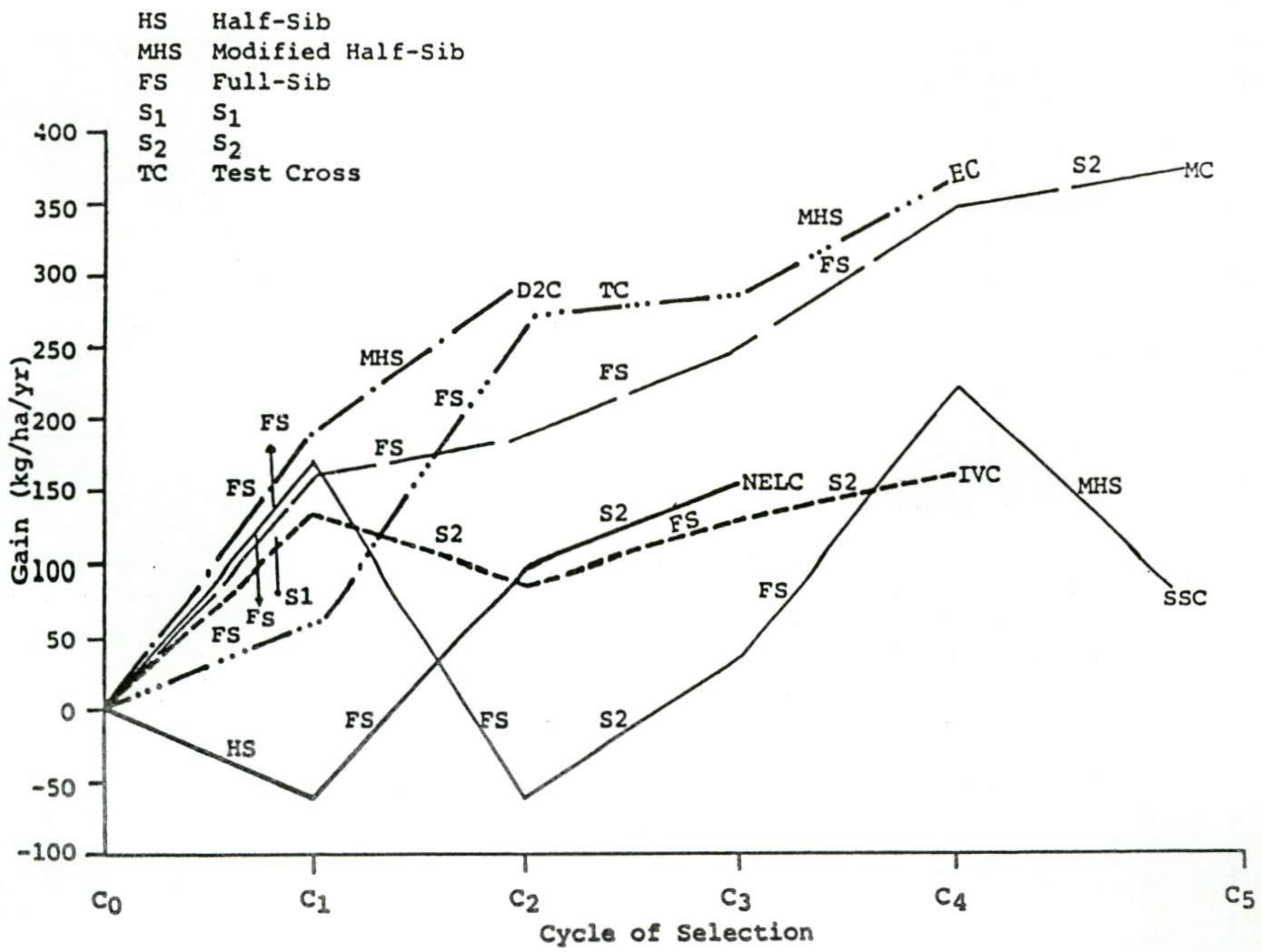

Figure 1. Gain in six composites for grain yield over cycles of selection using six selection methods.

Figure 2. **GENERALISED SCHEME FOR INTRAPOPULATION IMPROVEMENT IN PEARL MILLET.**

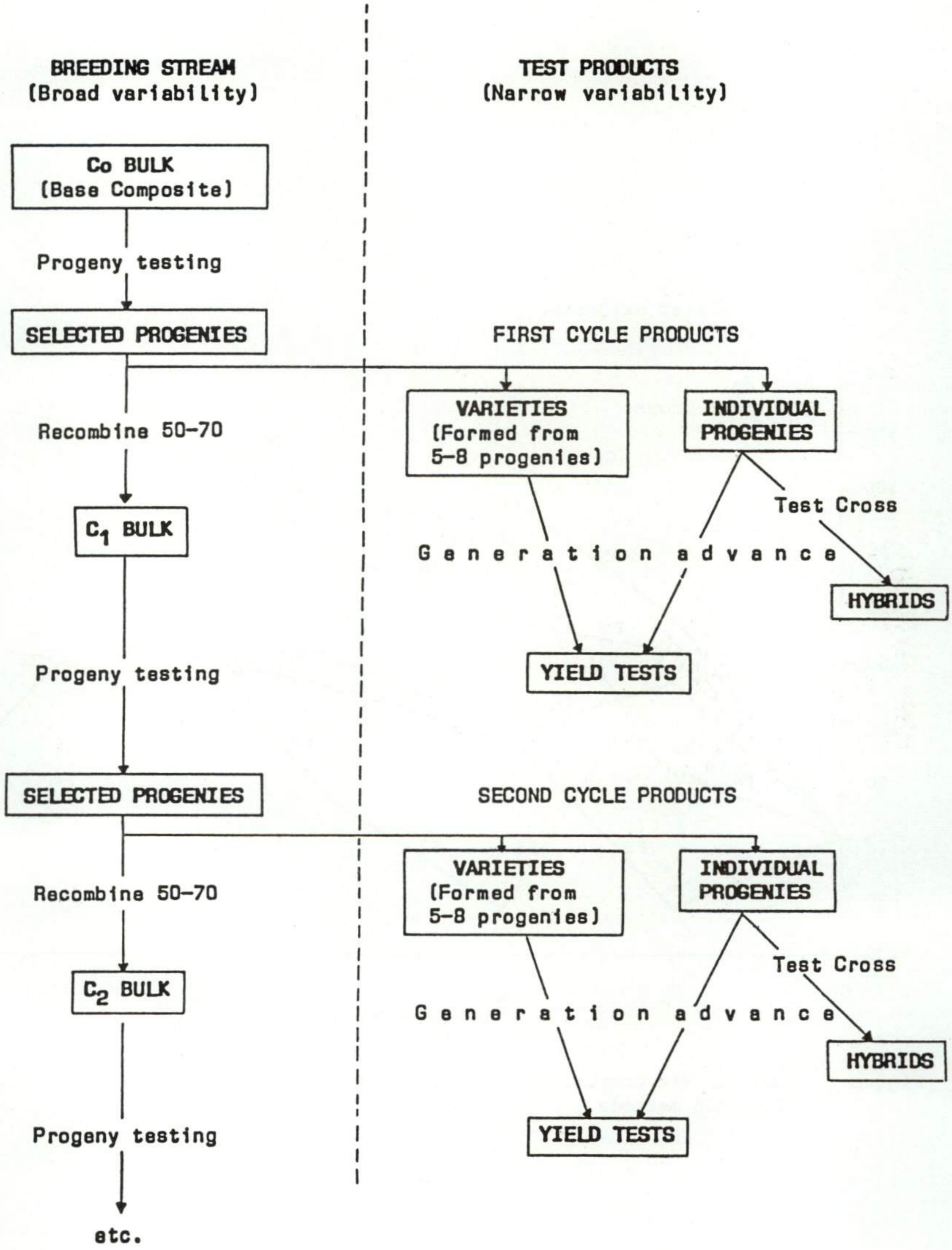

Table 6: Effect of recurrent selection on various characters[a] in six pearl millet composites

Composite	No. of cycles[b]	Grain yield (t ha $^{-1}$) Cycle Co	Grain yield Cycle Latest	Grain yield Gain per cycle[c] (%)	Downy mildew incidence (%) Cycle Co	Downy mildew incidence (%) Cycle Latest	Downy mildew incidence (%) Gain per cycle	Time to 50% bloom (d) Cycle Co	Time to 50% bloom (d) Cycle Latest	Time to 50% bloom (d) Gain per cycle	Plant height (cm) Cycle Co	Plant height (cm) Cycle Latest	Plant height (cm) Gain per cycle
Super Serere	5	1.93	2.11	1.8	2.1	1.0	-0.2	46.9	46.5	-0.1	222	221	-0.2
New Elite	3	2.36	2.57	2.6	1.4	0.0	-0.5	47.0	47.5	0.2	221	220	-0.1
Inter Varietal	4	2.11	2.39	1.9	1.9	1.6	-0.1	47.8	46.2	-0.4	221	213	-2.0
Medium	5	1.88	2.28	3.2	4.2	3.1	-0.2	45.2	43.4	-0.5	221	212	-1.7
Early	4	1.89	2.26	4.1	5.6	4.6	-0.3	38.8	40.3	0.6	189	193	1.0
D_2	2	1.97	2.27	5.0	7.5	4.9	-1.3	46.9	47.5	0.3	144	145	0.8

a Grain yield, time to 50% bloom, and plant height from mean of three locations. Downy mildew incidence (%) from downy mildew nursery, ICRISAT Centre, Patancheru

b Data included only up to 1982

c Gain per cycle (%) for grain yield calculated from regression analyses

Source: Andrews et al., 1985

It is the genetic gains per year, not per cycle, which are important. To complete one cycle of selection takes two seasons for the full sib method and four seasons for the S_2 method, i.e. two years and four years where off-season facilities are not available, and one year and two years, respectively, where off-season facilities can permit two seasons per year. Processing of multilocational data to utilize information on several traits to select the entries for recombination requires computational facilities. The unavailability of fast computational facilities may be restrictive, if not prohibitive, in the application of recurrent selection.

Downy-mildew resistance assumes as high a priority as grain yield in the recurrent selection program. Generally, two-stage selection for downy-mildew resistance is applied; an extra replication of the progenies under yield test is planted in the downy-mildew nursery and the data on resistance are used as an additional character while selecting the entries. Selected entries, at the recombination stage, are again planted in the downy mildew nursery in the off-season. Even at this stage any entry showing a high level of downy mildew is rejected, and downy mildew infected plants in other entries scored as resistant in the previous season are not used in recombination. This testing scheme ensures a gradual build-up in the resistance levels of the populations.

The development of diverse sources of smut resistance in an agronomically acceptable background formed the basis of a 'Smut Resistant Composite'. The advanced cycle bulk of this composite exhibits about 5% susceptibility under high smut pressure at ICRISAT. A high-yielding smut-resistant variety (ICMV82132) has recently been identified from this composite (Table 2). The smut resistance from this composite, and other sources recently developed by pathologists, will be fed into other composites which will, in turn, be subjected to recurrent selection for smut resistance. Most of the composites have some degree of variability for rust which is also being considered as an additional character in selecting the progenies for recombination. Other than the ergot-resistant lines developed by ICRISAT pathologists, almost all the materials (including composites) are highly susceptible to ergot. Fifty two ergot-resistant lines were planted for random mating in the summer of 1985 to allow recombination and selection for earliness, shorter height, and yielding ability, the three characters found unsatisfactory in the ergot-resistant lines.

From each cycle of recurrent selection, groups of 5-8 best progenies selected from performance data for each location, or the mean of all the test locations, are recombined to form varieties (Fig.2). Some of the best progenies are also sib-multiplied to form progeny varieties. Results over the years have shown that varieties yield more and are more stable than progeny varieties, and open-pollinated varieties from advanced cycles of selection perform better than those from initial cycles (Table 7). One variety, WC-C75, developed from the C_1 cycle, gave equivalent grain yield but 15% more fodder than a widely cultivated hybrid BJ 104 in 194 tests over seven years in AICMIP trials (Table 8), and was released in 1982 for general cultivation in India. This variety has shown <2% downy mildew as compared to about 10% on BJ 104. Varieties recently developed from several composites have yielded even more than WC-C75. A variety from the Inter Varietal Composite (ICMV 81111) yielded more than 10% over WC-C75 in several multilocational trials conducted during 1983-1984 (Table 9). There are indications that the latest varieties (tested in the 1984 ICRISAT advanced population trial) have even higher yield potential than those listed above.

The usefulness of the composites for the hybrid program has not been well tested, though several restorer progenies from composites have produced high-yielding hybrids. The inbred lines from some of the composites with shorter height may be of direct potential use. Others may release short segregants which prove to be useful. A rapid generation advance scheme has been undertaken to derive inbreds from composites. Evaluation of the inbred lines and their performance in initial test crosses will provide relevant information as to the potential direct use of these composites in the production of restorers.

Pedigree breeding

Classical breeding includes a number of methods such as pedigree breeding, backcrossing and their modifications. The application of pedigree selection to derive inbred lines has been quite effective in the development of synthetic varieties and hybrid parents (restorers as well as male-sterile lines). Unlike progenies in the recurrent selection program, pedigree-breeding progenies are visually evaluated for yielding ability and agronomic acceptability in unreplicated observation nurseries, generally planted at not more than two locations. Alternate generations are planted in the downy-mildew disease nursery to reject the susceptible ones and select within low-susceptibles.

Table 7. Comparative performance of varieties developed from initial and advance cycles of three composites, at various locations

Source composite	Variety	Grain Yield (t ha-1)	% of Check 1	Variety	Grain Yield (t ha-1)	%of check
	Varieties from third cycle[2]			Varieties from fifth cycle[4]		
Inter varietal Composite	IVC-H78	1.81	121	IVC-P8201	2.88	130
	IVC-A78	1.77	118	IVC-P8204	2.87	129
	IVC-P78	1.73	115	IVC-A82	2.79	126
	IVC-S78	1.70	113	IVC-B8201	2.65	119
				IVC-P8206	2.60	117
	Check	1.50		IVC-B8202	2.56	115
	SE	0.07		IVC-P8202	2.47	111
				IVC-P8205	2.47	111
				IVC-P8203	2.46	111
				Check	2.22	
				SE	0.10	
	Varieties from fourth cycle[2]			Varieties from sixth cycle[4]		
Medium composite	MC-H78	1.66	110	MC-A82	2.78	125
	MC-A78	1.53	102	MC-B82	2.60	117
	MC-P78	1.51	101	MC-P8205	2.48	112
	Check	1.50		MC-P8201	2.41	109
	SE	0.07		MC-P8202	2.36	106
				MC-P8207	2.35	106
				MC-P8201	2.33	105
				MC-P8205	2.28	103
				Check	2.22	
				SE	0.10	

Table 7. (Continued)

Source composite	Variety	Grain Yield (t ha-1)	% of Check 1	Variety	Grain Yield (t ha-1)	%of check
	Varieties from second cycle[3]			Varieties from fourth cycle[4]		
New elite composite	NELC-A79	2.60	118	NELC-P8204	2.81	127
	NELC-P79	2.49	113	NELC-P8202	2.53	114
	NELC-H79	2.45	111	NELC-P8201	2.46	111
	Check	2.21		Check	2.22	
	SE	0.09		SE	0.10	

1 WC-C75
2 Mean of 7 locations, 1979 rainy season
3 Mean of 4 locations, 1980 rainy season
4 Mean of 4 locations, 1983 rainy season
Source: Singh, *et al*., 1985.

Table 8. Grain yield, fodder yield and downy mildew resistance of pearl millet variety WC-C75 in All India tests[a] from 1977 to 1983.

	1977	1978	1979	1980	1981	1982	1983	Mean	Percent of BJ 104
Yield [t ha^{-1}	[27][b]	[33]	[23]	[27]	[30]	[24]	[30]		
WC-C75	1.63	2.07	1.76	1.85	1.99	1.85	1.79	1.88	101
BJ 104c	1.79	1.97	1.81	1.81	2.09	1.88	1.68	1.87	100
Local	1.36	1.92	1.61	1.47	1.42	1.86	-	1.61	86
Trial Mean	1.54	1.95	1.68	1.73	1.92	1.78	1.69	1.76	94
Fodder [t ha^{-1}]	[23][b]	[27]	[20]	[24]	[26]	[22]	[27]		
WC-C75	8.99	8.00	6.50	5.70	6.80	5.40	5.20	6.67	115
BJ 104[c]	6.84	6.60	5.70	7.00	6.00	5.50	4.10	5.82	100
Downy mildew [%][d]									
WC-C75	2.2	2.5	0.9	3.6	-	2.2	0.0	1.6	16
BJ 104	8.3	9.8	13.7	8.6	8.1	14.9	8.5	10.3	100
HB 3	93.5	72.3	42.1	-	-	-	-	69.3	-

Table 8. (Continued)

a Data from the All India Coordinated Millet Improvement Project [AICMIP] Annual Reports.

b Number of test locations.

c The most widely grown hybrid in India (used as a check in variety trials)

d % downy mildew incidence from AICMIP pathology nurseries where HB 3 or NHB 3) is the susceptible check.

Source: Andrews et al., 1985.

Table 9. Performance of variety ICMV 81111 in multilocational trials.

Trial	No. of locations	Grain yield [t ha^{-1}]		
		ICMV 81111	WC-C75 [Control]	Percent of WC-C75
PMPVT1	4	2.63	2.43	108
IPMAT1	10	2.20	1.98	111
AICMIP2	16	1.90	1.68	114

PMPVT = Pearl Millet Population Varieties Trial.

IPMAT = International Pearl Millet Adaptation Trial.

AICMIP = All India Coordinated Millets Improvement Project.

Source: 1: ICRISAT, 1983.

2: AICMIP Progress Report 1984 - 1985.

Pedigree breeding provides for the evaluation of initial progenies and their descendant lines over the years, hence providing information on the consistency of performance. Thus, several generations of visual selection precede their utilization for the development of synthetics and hybrids parents. The application of pedigree selection has resulted in the development of several promising synthetics. The first one of these was ICMS 7703 which was developed by intercrossing seven F_3-F_4 progenies derived from crosses involving inbred lines from Jamnagar (India) and partially inbred lines from Nigeria. This synthetic yields as well as WC-C75 (Table 10). After six years of testing in AICMIP trials in 155 tests, it was released for general cultivation in India.

ICMS 7704 is another synthetic which has yielded 6% more than WC-C75 in AICMIP trials conducted over five years (Table 11). The parents of this synthetic (six partial inbreds, derived from India x African crosses) were identified in the ICRISAT Uniform Progeny Nursery grown at Tandojam in Pakistan in 1976. It is the highest yielding open-pollinated variety in minikit tests and is awaiting general release for cultivation in India.

Smut-resistant lines were pedigree-selected by pathologists and have also been utilized for the development of synthetics. ICMS 8283 has recently been identified as a high-yielding synthetic with a high smut-resistance level (Table 2).

Ergot-resistant lines were also used for the development of ergot-resistant synthetics. Since ergot-resistant lines have a narrow genetic base, intercrossing among them did not give sufficient heterosis for yield so they did not yield more than 95% of WC-C75 under ergot-free environment. Further, these synthetics were later in maturity. Where some ergot-susceptible unrelated lines were also used along with ergot-resistant lines to bring in genetic diversity to generate heterosis at yield-component loci, synthetics with competitive yield levels could be produced but they turned out to be susceptible to ergot.

Pedigree selection in composite progenies and in populations derived from crosses between varieties and inbred lines has led to the development of restorers, several of which have produced very high-yielding hybrids. Pedigree selection has also been applied for the development of non-restorer progenies to be subsequently converted into male-sterile lines (A lines).

Table 10. Performance of synthetic variety ICMS 7703 in All India Coordinated (AICMIP) trials 1978-1983

Entry	1978	1979	1980	1981	1982	1983	Mean
			Grain yield (t ha^{-1})				
Location	21	23	27	30	24	30	-
ICMS 7703	1.93	1.83	1.85	2.14	1.89	1.75	1.90
WC-C75	-	1.76	1.85	1.99	1.85	1.79	1.85
BJ 104	1.94	1.81	1.81	2.09	1.88	1.68	1.87
			Fodder yield (t/ha)				
Location	21	20	24	26	22	27	-
ICMS 7703	7.4	6.7	7.1	6.7	5.7	5.0	6.4
WC-C75	6	6.5	5.7	6.8	5.4	5.2	5.9
BJ 104	5.7	5.7	7.0	6.0	4.5	4.1	5.5
			Downy mildew (%)				
ICMS 7703	4.7	3.8	1.6	2.5	3.8	5.4	3.6
WC-C75	2.8	0.9	3.6	3.4	2.3	2.2	2.5
BJ104	9.8	13.7	8.6	16.0	14.9	21.3	14.1

Source: S.B. Chavan, unpublished.

Table 11. Performance of synthetic ICMS 7704 in the All India Coordinated Millets Improvement Project Trial

	Grain yield(t ha-1)						
Variety	1980	1981	1982	1983	1984	Mean	Downy mildew (%)
ICMS 7704	2.13	2.05	1.88	1.80	1.71	1.91	2.5
WC-C75 (check)	1.83	1.99	1.85	1.79	1.58	1.81	2.3

Source: Coordinator's review AICMIP Millets Workshop, 1985.

Conversion of B lines into A lines requires a backcross program, using the B line as the recurrent parent. If the backcross program starts with B lines which are only partially inbred, pedigree selection within B lines and backcross generations, as well as between A/B pairs, is practised to select for uniformity within the lines, and to select for similarity between (potential) A lines and B lines for several plant characters. The best example of a joint backcrossing and pedigree selection in pearl millet is the development of a male-sterile line 81A (Andrews and Anand Kumar, 1982). This male-sterile line was developed by irradiating dry seeds of Tift 23DB, a highly susceptible maintainer line, with 30 kR of gamma rays from a ^{60}Co source. M_0 generation plants were selfed and grown head-to-row in a downy-mildew disease nursery. Dwarf, vigorous, and disease-free plants (with induced downy-mildew resistance) were selected and selfed as well as crossed to Tift 23DA (an A_1 system male-sterile line with proven, high general combining ability). The process of pedigree selection and backcrossing into A_1 cytoplasm was repeated twice a year for six generations in the downy-mildew nursery at ICRISAT Center. The male-sterile line 81A and its maintainer line 81B were finally chosen on the basis of phenotypic similarity between the two, vigour, seed set, downy-mildew resistance and on the results of combining ability tests.

The application of combined pedigree selection and backcrossing has led to several promising and diverse male-steriles (Table 12) which are being utilized for the production of experimental hybrids.

A single dominant gene for rust resistance has been identified (Andrews et al., 1985) which is being transferred into male-sterile lines using a backcrossing procedure. Backcross transfer of polygenic traits is not a universally accepted method in conventional breeding. However, there is an example of success with this method (Knott and Talukdar, 1971). Ergot resistance, which has been shown to be controlled by polygenic recessives, is currently being transferred by backcrossing it into hybrid parents and there are initial indications of its success (B. S. Talukdar, personal communication).

The d_2 dwarfing gene was transferred principally from GAM 73 into seven normal (tall) composites. The method used is termed a "sidecar method". It is a slight modification of the conventional backcross procedure in which the recurrent parent was not the same composite bulk; instead, as the backcrossing continued, the composite bulks from advanced cycles of selection were used as recurrent parents as compared to initial cycle bulks used in the initial crossing or early backcross stages. The dwarf composite versions derived after three backcrosses have been compared with their tall (counterpart) composites in yield tests conducted over two locations for three years. Results have shown some of the dwarf bulks yielding the same or more than their tall composite bulks (Table 13).

Table 12. Morphological characteristics of some pearl millet male-sterile lines bred at ICRISAT Cente, Summer, 1984.

Character	841	81A	833A	834A	842A	843A	SE
Time to 50% bloom (d)	51	61	44	49	49	42	+0.9
Plant height (cm)	85	75	92	113	102	72	+5.9
Head Length (cm)	15	20	26	17	16	12	+1.4
Head girth (cm)	5.2	5.2	6.6	8.6	6.8	6.3	+0.2
Effective tillers/plant	4.0	2.3	3.2	2.6	2.1	4.1	+0.7
1000 grain mass (g)	6.3	7.6	8.7	9.6	11.7	12.5	+0.7
Downy mildew (%)	1.2	7.5	0.4	0.0	0.9	11.6	+0.7

1. Data from ICRISAT Center Downy Mildew Disease Nursery in which susceptible check hybrid NHB3 had 96.9% downy mildew.

Table 13. Performance of recurrent (tall) pearl millet composites and their d_2 dwarf versions derived after third backcross (based on three tests over 2 years).

Height Character	Composite group[1]	EC	MC	WC	IVC	SSC	NC	EXB	Control[2]	SE
Grain yield ($t\ ha^{-1}$)	Tall	2.57	2.44	2.47	2.51	2.48	2.48	2.13		+87
	Dwarf	2.32	2.55	2.38	2.48	2.39	2.70	2.37	2110 -	
Plant height (cm)	Tall	193	206	203	215	220	24[illegible]	248		+2.5
	Dwarf	144	144	140	148	147	167	163	140	+0.4 -
Ear length (cm)	Tall	23	25	24	26	26	32	30		+ .4
	Dwarf	25	28	26	29	27	33	33	32	-
Time to 50% bloom (d)	Tall	42	43	45	46	46	47	50	45	+0.3
	Dwarf	42	44	47	46	47	49	50		-

1. EC = Early composite; MC= Medium Composite; WC = World Composite; IVC = Intervarietal Composite; SSC = Super Serere Composite; NC = Nigerian Composite; EXB = ExBornu.

2. Control = GAM 73 x K77.

The availability of eight dwarf populations (including another dwarf population in the population improvement program) provides an enormous variability in d_2 height range and with good yield potential for utilization either directly as open-pollinated populations (or in the development of open-pollinated varieties) or for utilization as parents. Two of these populations (Nigerian Composite (d_2) and Ex Bornu (d_2)) have been crossed with 3 male-sterile lines (834A, 842A, 843A). The evaluation of top cross hybrid yields indicates that these dwarf populations would be valuable sources for the development of inbred lines to be used on 834A. At the same time, top-cross hybrids are being currently used for backcrossing and three-way crossing with B lines to develop male-sterile lines with long heads.

SUMMARY

Pearl millet is a major cereal grown on about 26 million hectares, principally in the semi-arid regions of the Indian subcontinent and Africa. It is almost entirely grown as a rainfed crop with negligible purchased inputs. As a consequence, the crop faces numerous hazards (diseases, pests, parasites, birds, drought, poor plant stand and low fertility environments). Among the diseases, downy mildew is most serious in intensity as well as distribution. Ergot, smut and rust are the other diseases of economic importance but they do not occur as regularly as downy mildew and are of secondary importance, although they are quite serious in certain areas, and have the potential to become devastating with changes in agricultural system. Pests, a parasitic weed (Striga) and a weedy relative of pearl millet (shibra) are more serious in western Africa than other millet growing regions. Birds are serious problems everywhere millet is grown. Drought, poor plant stand and low fertility are also common problems of all the millet growing regions. The poor sink capacity of traditional millets with 15-20% harvest index is a basic problem of the millets leading to low grain yields.

The development of effective large-scale field-screening techniques, and application of a range of breeding methods (recurrent selection, pedigree breeding, backcross breeding) at ICRISAT Center has led to the development of diverse breeding materials with high-yield potential and high levels of disease resistance. The success of breeding for resistance for yield reducing factors has been commensurate with the development of basic knowledge, availability of screening and yield testing facilities, and the importance, nature and level of complexity of the stress factors and their relationship to grain yield. Thus, for instance, although drought is the most serious yield-reducing factor, the lack of precise understanding of the drought-resistance mechanism and its genetic control (perhaps too complex) has been a limiting factor in drought-resistance breeding. In contrast, development of sufficient basic knowledge, the development of large-scale field screening techniques, and perhaps simpler genetic control, have made it possible to achieve much rapid progress in breeding for downy mildew resistance; the breeding for resistance to ergot, smut and rust has recently been stepped up and the progress has been satisfactory. Very little research work has been done in developing large-scale effective field-screening techniques and identifying sources of resistance to pests, Striga and birds. As a result, no worthwhile breeding progress has been made in these areas.

Both recurrent selection and pedigree selection have been equally effective in developing high-yielding varieties and hybrids, some of which have already been released for cultivation and are getting rapid acceptance from farmers. Others are still in the pipeline awaiting release in the near future. The breeding materials and breeding/screening methods developed at ICRISAT are proving useful and finding applications with millet programs elsewhere as well. ICRISAT Center millet program has done considerable work on the genetic modifications of plant types. As a result, materials of diverse range (particularly different height and maturity classes) are now available for use in other millet breeding programs.

ACKNOWLEDGEMENTS

We are grateful to Drs. S. Appa Rao, R.P. Thakur, S.D. Singh, B.S. Talukdar, S.B. Chavan, and P. Singh, for generously allowing us to use unpublished data in the preparation of this paper.

REFERENCES

Allard, R.W. 1960. Principles of Plant Breeding. New York and London, John Wiley and Sons.

Andrews, D.J. and Anand Kumar, K. 1982. Induction of downy mildew resistance in pearl millet male sterile Tift $23d_2$. Mutation Breeding Newsletter No, 20 IAEA, Vienna, pp.1-3.

Andrews, D.J., Mughugho, L.K. and Ball, S.L. 1984. Sorghum and pearl millet production in Africa - problems and prospects with new varieties. Advancing Agricultural Production in Africa, Arusha, Tanzania, 12-18 February 1984.

Andrews, D.J., Rai, K.N. and Singh, S.D. 1985. A single dominant gene for rust resistance in pearl millet. Crop Sci. 25:565-566.

Ball, S.L. and Pike, D.J. 1984. Intercontinental variation of Sclerospora graminicola. Ann. Appl. Biol. 104:41-51.

Bidinger, F.R., Maiti, R.K. and Raju, P.S. 1985. Research on see dling vigour in pearl millet. Millet Physiology Progress Report, May 1985.

Bidinger, F.R., Mahalakshmi, V., Talukdar, B.S. and Alagarswamy, G. 1983. Improvement of drought resistance in pearl millet. In Drought Resistance in Crops with Emphasis on Rice. IRRI, Los Banos, Philippines, pp. 357-377.

Bilquez, A.F. 1975. Improvement of millet in Senegal; analytical summary of the main results obtained during the first four years of work (Fr). Dakar, Senegal, ISRA.

Chantereau, J. and Etasse, C. 1976. Creation de populations naines de mil pennisetum (Pennisetum typhoides Stapf) au Niger. Agron. Tropic. 31:254-257.

Coutin, R. and Harris, K.M. 1968. The taxonomy, distribution, biology and economic importance of the millet grain midge (Geromyia penniseti (Felt). gen., n., comb. n., (Dipt., Cecidomyiidae). Bull. 59:259-273.

FAO. 1978. Production Year Book 32, FAO, Rome.

Ferraris, R. 1973. Pearl millet (Pennisetum typhoides). Review Series No.1/1973. Commonwealth Bureau of Pastures and Field Crops.

Gahukar, R.T. 1984. Insect pests of pearl millet in West Africa: A Review Tropical Pest Management 30: 142-147.

Gautam, R.C. 1982. Pearl millet agronomy through half a decade (1977 - 1981). Presented at the All India Coordinated Millet Improvement Project Workshop. Coimbatore, Tamil Nadu, 26-28 April 1982.

Hallauer, A.R. and Miranda, J.B. 1981. Quantitative Genetics in Maize Breeding. Iowa State University, Ames, Iowa.

Harinarayana, G. 1977. All India Coordinated Millets Improvement Project, Objectives, Organization and Achievements. Presented at the International Pearl Millet Workshop, Hyderabad, India 29 August - 2 September 1977.

Knott, R.D. and Talukdar, B.S. 1971. Increasing seed weight in wheat and its effect on yield, yield components, and quality. Crop Sci. 11: 280-283.

Krishnamachari, K.A.V.R. and Bhat, R.V. 1976. Poisoning of ergot bajra (pearl millet). Man.Ind.J.Med.Res. 64:1624-1628.

Rachie, K.O. and Majmudar, J.V. 1980. Pearl Millet. Pennsylvania State University Press.

Ramaiah, K.V., Parker, C., Vasudeo Rao, M.J. and Musselman, L.J. 1983. Striga identification and control hand book. Research Bulletin No.15. International Crops Research Institute for the Semi-Arid Tropics, ICRISAT Patancheru, Andhra Pradesh, India.

Ramakrishnan, T.S. 1971. Diseases of millets. New Delhi, Indian Council of Agricultural Research.

Safeeulla, K.M. 1977. Genetic vulnerability: The basis of recent epidemics in India. Annals of the New York Academy of Sciences, 287: 72-85.

Singh, P., Rai, K.N., Witcombe, J.R. and Andrews, D.J. 1985. Population breeding methods in pearl millet improvement. In Progress in Plant Breeding II, Butterworths, London (in press).

Soman, P., Peacock, J.M. and Bidinger, F.R. 1984. A field tech nique to screen seedling emergence of pearl millet and sorghum through soil crusts. Exp. Agr. 20:327-334.

Soman, P., Bidinger, F.R. and Jayachandran, R. 1985. Evaluation of genotypic differences in seedling emergence through soil crusts under field conditions. Paper presented at the International Symposium on the Assessment of Soil Surface Sealing and Crusting, Ghent, Belgium, 21-25 September 1985.

Subba Rao, N.S. 1984. Cereal nitrogen fixation research under the BNF Coordinated Project of the ICAR. Proceedings of the working group meeting on cereal nitrogen fixation, ICRISAT, 9-12 October 1984, ICRISAT, Hyderabad, India.

Sundaram, N.V. 1975. Ergot of bajra. In S.P. Raychandhri, A. Varma, K.S. Bhargava and B.S. Mehotra (eds.), Advances in Mycology and Plant Pathology. New Delhi, India, (Tandon's Birthday Celebration Committee), pp.155-160.

Thakur, R.P. and Williams, R.J. 1980. Pollination effects on pearl millet ergot. Phytopathology 70: 80-84.

Thakur, R.P., Williams, R.J. and Rao, V.P. 1982. Development of resistance to ergot in pearl millet. Phytopathology 72: 406-408.

Thakur, R.P., Williams, R.J. and Rao, V.P. 1983a. Control of ergot in pearl millet through pollen management. Ann. Appl. Biol. 103: 31-36.

Thakur R.P., Subba Rao, K.V. and Williams, R.J. 1983b. Evaluation of a new field screening technique for smut resistance in pearl millet. Phytopathology 73:1255-1258.

Thakur, R.P., Talukdar, B.S. and Rao, V.P. 1983c. Genetics of ergot resistance in pearl millet. Paper presented at International Congress of Genetics, New Delhi, India 12-21 December 1983.

Verma, S.K. 1980. Field pests of pearl millet in India. Tropical Pest Management 26: 13-20.

Wani, S.P. 1984. Cereal nitrogen fixation - problems and potentialities. Proceedings of the Working Group Meeting on Cereal Nitrogen Fixation, 9-12 October 1984, ICRISAT, Hyderabad, India.

Wani, S.P., Chandrapalaiah, S. and Dart, P.J. 1985. Response of pearl millet cultivars to inoculation with nitrogen-fixing bacteria. (In press.)

Wells, H.D., Burton, G.W. and Hanna, W.W. 1973. *Puccinia subsriata* var. *indica*. A new rust with devastating potential on pearl millet in the south east. Phytopathology 63:449.

Williams, R.J. Singh, S.D. and Pawar, M.N. 1981. An improved field screening technique for downy mildew resistance in pearl millet. Plant Disease 65:239-241.

PEARL MILLET BREEDING

D I S C U S S I O N

Doggett

That was an excellent presentation of an excellent program, illustrating clearly the benefits to be obtained through recurrent selection. It is of particular interest that the new "varieties" of millet are as good as the commercial hybrid. In many parts of Africa, it will take years before sorghum hybrids can be released and exploited because of the lack of seed multiplication systems and the shortage of trained manpower. Recurrent selection should be given far more attention in Africa, with some exchange between the breeding populations.

Rai

Pearl millet has an out-crossing rate of 85 - 90%, whereas sorghum has an out-crossing rate of the order of 10%. Thus pearl millet open-pollinated varieties can exploit more heterosis than sorghum open-pollinated varieties. As a consequence, in pearl millet the difference between hybrids and open-pollinated varieties will be much less than in sorghum where hybrids can have a greater edge over varieties.

Doggett

The use of male sterility makes possible high levels of outcrossing in sorghum. Bhola Nath's work at ICRISAT shows that steady progress can be made by recurrent selection in populations, just as has been done for pearl millet. We need work of this kind here in Africa.

Omolo

On recurrent selection, I noticed a number of methods were used on a number of populations. Is there any way of telling which one of the methods made faster progress? If there were no differences, then what were the factors that determined the change from one method to another within the same population?

Rai

There is no way of telling which method is better than the other. In fact, four recurrent selection methods applied on a composite showed that none was better than the other. To ensure that any one year is not overloaded with progeny trials, adjustments were made to apply different recurrent selection methods as some take one year to complete a cycle whereas others take two years, and considering the availability of two growing seasons per year at ICRISAT Center.

Taye

Striga infestation is limiting sorghum, millet and other food grains production in much of Africa. I feel that ICRISAT should intensify research on Striga in Africa in co-operation with national research programs where this parasite is becoming more and more of a constraint for sorghum and millet production.

Rai

Only Striga asiatica is found in India whereas the major species of concern in Africa is Striga hermonthica.

PROBLEMS AND PROSPECTS IN SORGHUM NUTRITIGN AND UTILIZATION

John Axtell and Gebisa Ejeta*

Hulse, Laing and Pearson (1980) have published an extraordinarily comprehensive and review entitled "Sorghum and the Millets: Their Composition and Nutritive Value". These authors reviewed more than 1,700 original references relating to the nature, composition and nutritive value of these cereals with the aim of furthering research in this area. Their introduction includes the following statement which sets the stage for our presentation this morning: "Sorghum and the principal millets, apart from their use in animal feeds, are the staple foods of many of the world's poorest people: people whose nutrient supply is invariably at risk. The nutritional quality of the grains should therefore be a matter of primary consideration for all those working towards their genetic and agronomic improvement." Our presentation this morning will review the status of current research on nutritional quality of sorghum and then focus on prospects and opportunities for future research.

We have been studying three major components of nutritional quality in grain sorghum. First, protein availability is apparently limited in some sorghum genotypes by the presence of unidentified polyphenolic compounds located primarily in the testa layer of the grain. These pigmented compounds have not been well characterized chemically and are referred to generically as "tannins". Second, the protein quality of sorghum is limited by the low lysine content of the grain which reflects the high prolamine content of the endosperm. If one looks at the essential amino-acid composition of sorghum grain, in comparison with monogastric nutritional requirements, it is obvious that lysine is deficient and that there is great excess of leucine.
The methionine content of sorghum is low, but considering the cystine content of 1.5%, the overall sulphur amino-acid content approaches the weanling rat requirement. The tryptophan content of sorghum seems to be adequate in contrast to the low tryptophan content in normal maize. Third, recent nitrogen-balance experiments by MacLean et al.(1981) suggest that protein digestibility of some low-tannin whole-grain sorghum foods is low when fed as cooked sorghum gruel to young children.

---

*Professor of Genetics and Assistant Professor, respectively, Department of Agronomy, Purdue University, West Lafayette, Indiana, 47907, USA.

TANNINS

Butler (1981) has presented an excellent review of the biochemistry of sorghum tannins and on the effects of these polyphenols on sorghum-grain quality. We will simply review here the basic observations on the interaction between tannis and nutritional value of sorghum grain. Schaffet et al. (1984) first recognized that the in vitro dry matter digestibility (IVDMD) of sorghum grains varied significantly between genotypes, and that the catechin equivalent values for tannin content were negatively correlated with IVDMD, as shown in Table 1. This was an extremely important observation because it explained the discrepancies which had previously been observed between protein quality and biological value in rat feeding experiments. Based on the amino- acid composition of sorghum grain one would predict that the biological value of any particular variety of sorghum grain would be directly proportional to its lysine content. This, in fact, is true for low-tannin sorghum genotypes. The data in Figure 1, however, show that lysine is not the first limiting component of biological value for a group of high tannin sorghum lines from the world collection. There is an important interaction between tannin content and protein quality in sorghum which is not found in any of the other cereals. Cummings and Axtell (1973) demonstrated this experimentally by feeding whole seed and dehulled high-tannin sorghum grain IS 8260 as shown in Figure 2. Rat growth is poor for the whole grain IS 8260 with and without supplemental lysine. In contrast, dehulling IS 8260 grain improves biological value substantially, and also allows a significant rat growth response to the addition of supplemental lysine. A similar technique was used in this study to determine the quantitative effects of tannins on biological value. Using varying proportions of high tannin sorghum grain mixed with a dehulled low tannin counterpart, we were able to provide diets containing a range in tannin content which were essentially isogenic comparisons. Data from this study are shown in Figure 3.

The biological value, as measured by rat weight gain, is significantly reduced by increasing levels of tannin in the diet. We can conclude from these data that tannins reduce the biological value of grain sorghum for monogastric animals. The cause of this reduction is not completely understood. Our present hypothesis is that the seed proteins become complexed or bound with the tannins of the whole grain, and that the complexed proteins are substantially less available for utilization by monogastric animals. It is very important to recognize this tannin interaction with protein quality when assessing the biological value of any grain-sorghum variety, since failure to consider the biological effects of tannins has led to substantial confusion in past studies of sorghum nutritional quality.

Table 1. Per cent crude protein, 96-hour *in vitro* dry matter disappearance and undigestible protein in eight sorghum genotypes

Genotypes	Catechin equivalent	Crude protein	96-hour IVDMD	Undigestible protein residue
		% of dry matter		
IS0062	0.29	13.78	94.8a*	1.13
IS0418	0.27	12.11	93.1a	1.62
IS8165	4.28	11.26	88.8b	2.80
IS0616	5.93	14.20	83.0c	4.73

* Means in a column followed by the same letter do not differ significantly at the 0.05 level of probability using Newman-Keul's test.

Future progress in research on tannins will depend on a better understanding of the biochemistry of sorghum tannins and their interaction with seed proteins. Detoxification of sorghum tannins by alkali treatment seems to be a clear possibility which will be especially useful in animal feed utilization. Research on removal of tannins from the outer layers of the sorghum grain by pearling or milling will also provide an important future solution to the problem in grains to be utilized for human consumption.

PROTEIN QUALITY

Two genetic mutants, one naturally occurring and one induced, have been identified that increase the lysine content of the sorghum endosperm and improve protein quality of the grain. A brief review of the origin of these mutants, and recent results of experiments on the relationship between improved protein quality and total grain production in sorghum, is presented.

The Ethiopian high-lysine gene

Singh and Axtell (1973) screened 10,000 entries in the World Sorghum Collection and identified two floury endosperm varieties from Ethiopia that contained a gene that significantly increased the level of protein in the grain and also increased the lysine concentration of the endosperm proteins. The screening process involved cross-sectioning seeds from each entry to identify those with floury endosperm phenotypes and then evaluating grain samples from those selected entries for protein and lysine concentration.

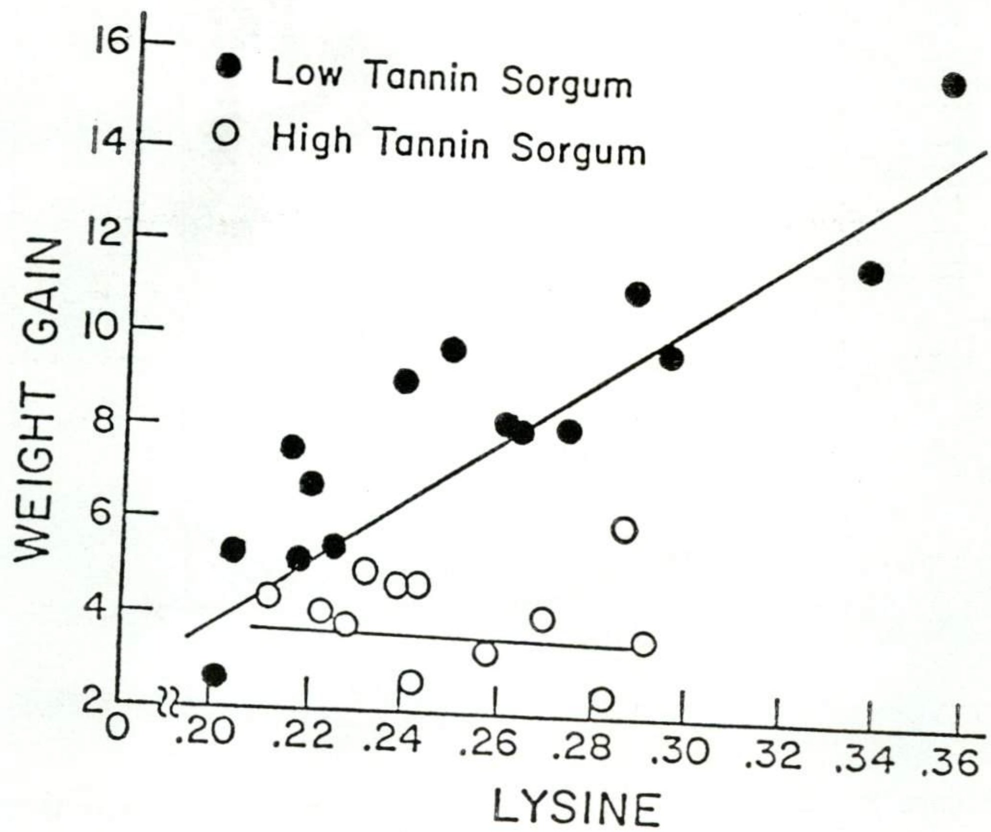

Figure 1. Relationship of biological value to lysine concentration (g/100 g sample) in high and low tannin sorghum lines from the world collection in a 14-day weanling rat feeding experiment.

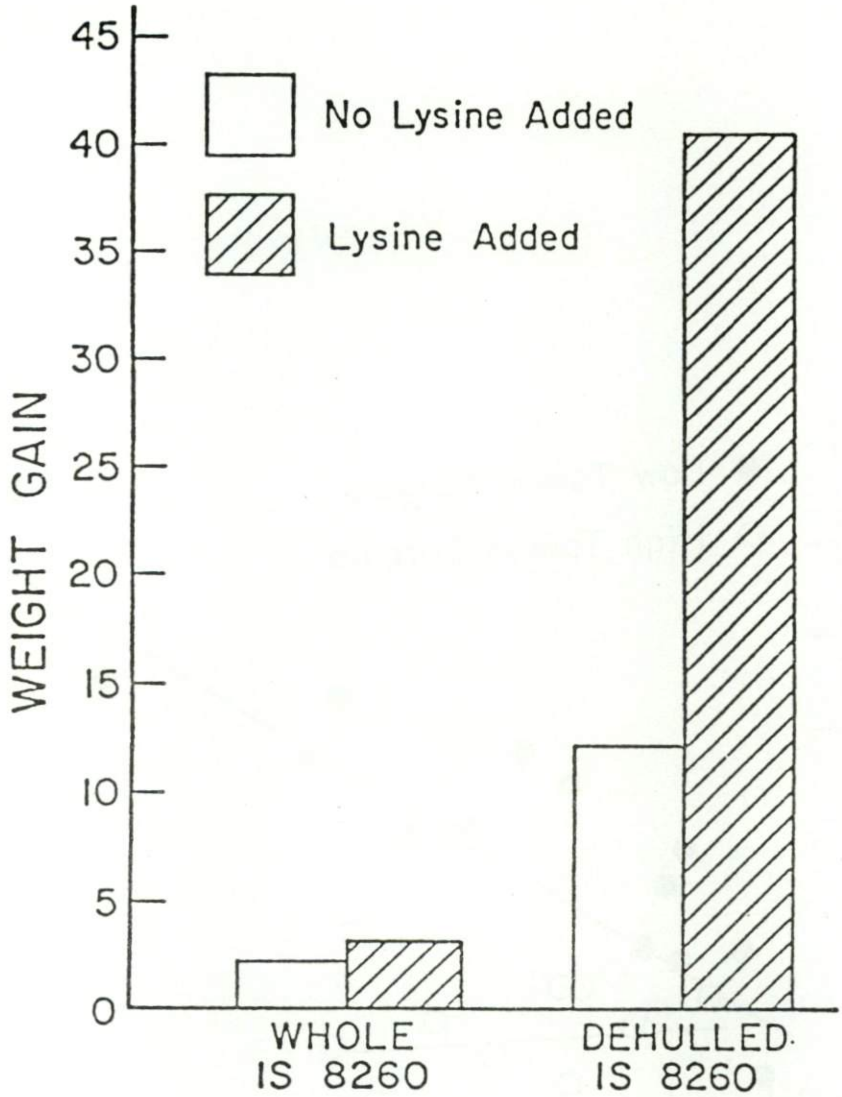

Figure 2. Biological value of whole and dehulled grain in high lysine sorghum line IS 8260 when fed to weanling rats with and without lysine supplementation in a 14-day feeding experiment.

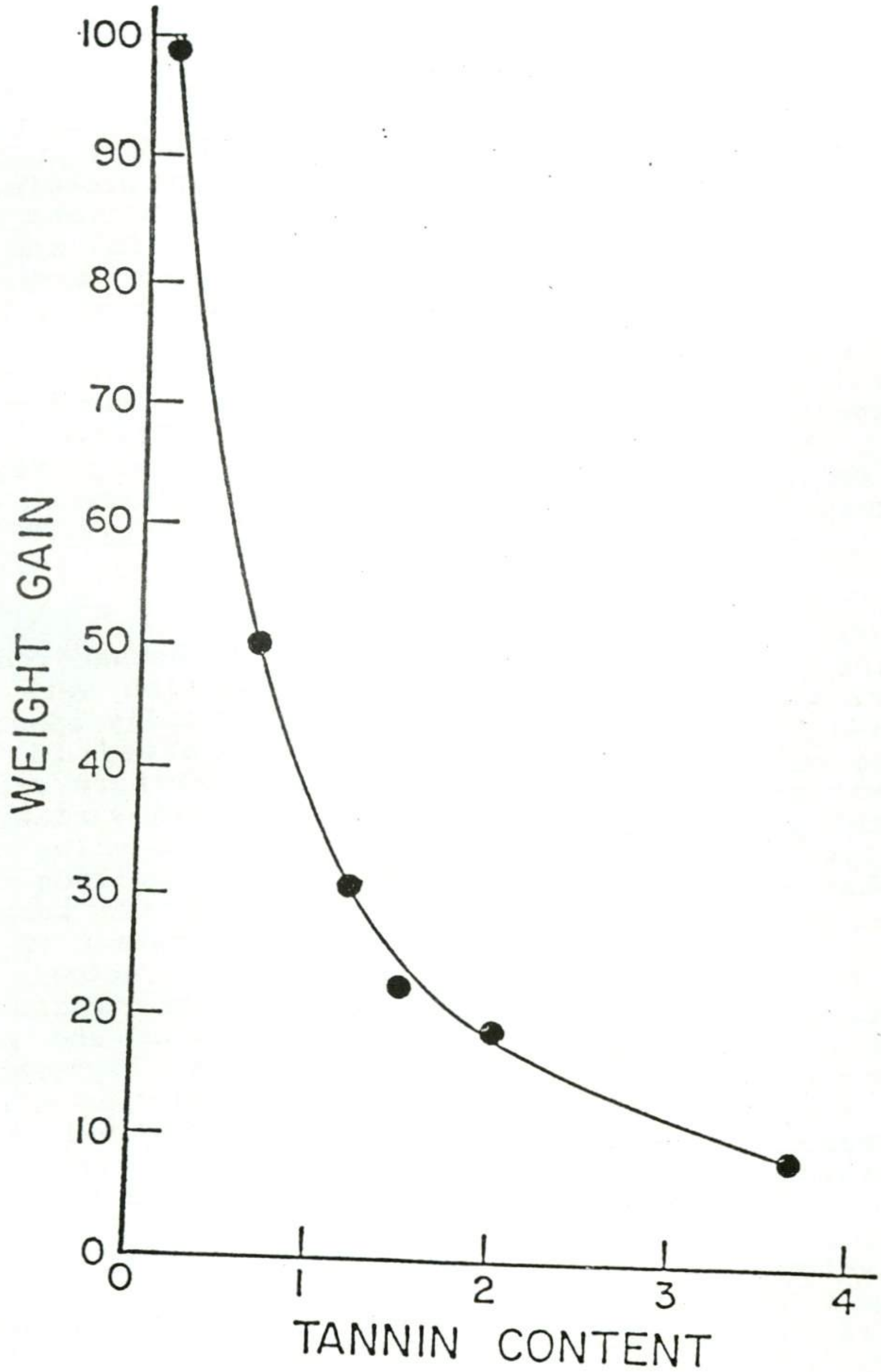

Figure 3. Effect of tannin content (expressed as catechin equivalents) on the biological value of sorghum grain in a 28-day weanling rat feeding experiment.

Sixty-two floury endosperm lines were identified, of which two (IS-11167 and IS-11758) had a significantly higher lysine content than normal sorghum. These lines contain 15 - 17% protein in comparison with normal checks averaging about 12% protein. The lysine content of the Ethiopian high-lysine selections is approximately 3.1% (expressed as per cent of protein) and 0.50% (expressed as per cent of sample) in comparison with normal sorghum values of 2.0 and 0.26%, respectively (Axtell et al., 1974).

The biological value of the Ethiopian high lysine grain is also significantly higher than normal sorghums in isonitrogenous rat-feeding experiments (Singh and Axtell, 1973). It has been established that the concentration of alcohol-soluble proteins is significantly reduced in high-lysine endosperm, relative to values present in normal sorghum endosperm (Jambunathan, et al, 1975).

Utilization of high-lysine varieties in Ethiopia

A collection trip was made in 1973 to determine whether the high lysine varieties identified in the World Collection were being cultivated by farmers in Ethiopia. The lines originally identified from the World Germplasm Collection were obtained in Wollo Province in the central highlands of Ethiopia. Farmers continue to grow these varieties in mixed plantings of sorghum varieties in this area of Ethiopia. A large number of varieties similar to the original high-lysine variety were collected, in addition to an equivalent number of normal varieties for comparative purposes. Ejeta (1976) has evaluated the protein and lysine content of grain from high-lysine and normal varieties grown under actual field conditions in Ethiopia. Figure 4 illustrates the lysine and protein concentration in this series of high-lysine and normal sorghum varieties. The mean lysine concentration, expressed as per cent of protein, was 2.88 for the high-lysine entries and 2.17 for the normal sorghum varieties grown in the same environment. Protein values were 15.7 and 11.4%, respectively. It seems likely that the high-lysine gene has been present in Ethiopia for a long period of time, since there is great diversity in panicle morphology, maturity and plant height among the high-lysine genotypes collected. The farmers roast the heads of the high lysine varieties in the late dough stage and at the grain in mixtures with grain from normal sorghum varieties prepared in a similar way. There is general recognition by the farmers that the yield of high-lysine varieties is significantly less than normal varieties. Estimates given in Table 2 show that the high-lysine cultivars grown in Ethiopia yield approximately 72 per cent of normal check varieties (Gebrekidan, 1977). The reason given by farmers for growing these varieties is that the high-lysine grain has superior flavour qualities and improved palatability when roasted.

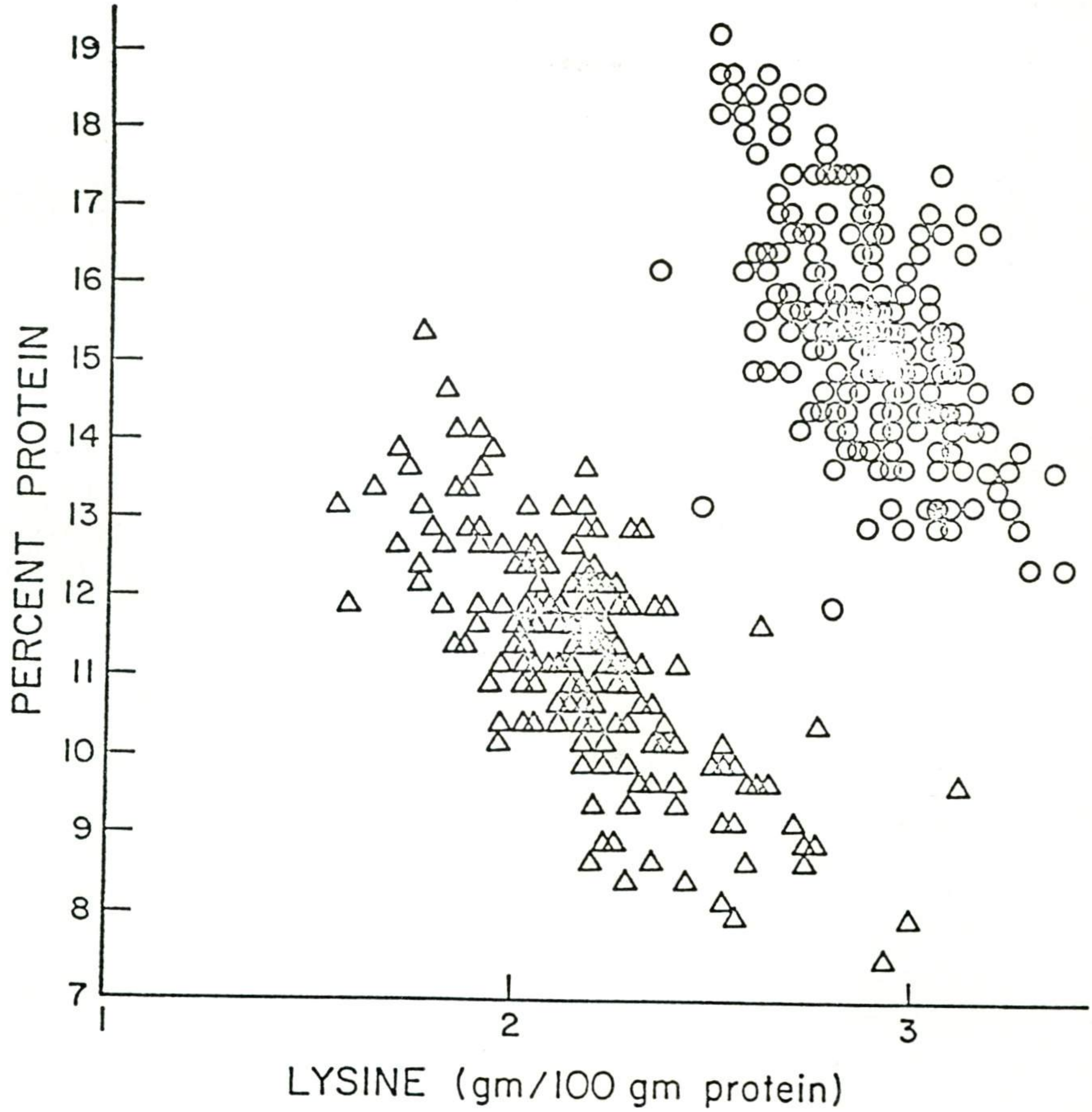

Figure 4. Relationship of protein and lysine in normal and high-lysine sorghum lines collected from the same environment. Circles represent data from dented high lysine varieties whereas triangles represent data from plump normal cultivars collected in the same geographic region.

There is a good opportunity to utilize these high-lysine varieties in African countries as high-protein, special-purpose sorghum varieties. The protein concentration is increased by about 30%, along with the significant increase in protein quality. The grain from these varieties is recognizably different for marketing purposes because of the somewhat dented kernel phenotype of the mature grain. The flavour characteristics also appear to make these varieties quite acceptable for human consumption. We propose that these Ethiopian high-lysine varieties should be utilized in rural populations as special-purpose sorghums for people who have a high protein requirement. It should be possible for farmers in rural areas to produce an adequate quantity of high-lysine sorghum grain for use as a weaning food and a supplement for pregnant women and nursing mothers on a small section of their farm. It may also be possible to develop a marketing system whereby these grains can receive a market premium when sold in the cities.

Table 2. Mean grain yields of 12 high-lysine sorghum cultivars and two check cultivars evaluated at Alemaya, Ethiopia

	Grain yield (t/ha)		
Sorghum type	1975	1976	Mean
High lysine	2.0	2.5	2.3
Normal	2.9	3.5	3.2

Source: Gebrekidan, 1977.

A chemically induced high-lysine mutant

Mohan (1975) utilized chemical mutagenesis to induce a second high lysine gene mutation in sorghum. The parent line used for the mutagen treatments was a photoperiod insensitive, three-dwarf sorghum line with relatively broad agronomic adaptability. The parent line also had a colourless pericarp and a translucent (vitreous) endosperm so that progeny from the mutagen treatments could be screened for opaque mutant kernels over a light box. Selfed seed was treated with diethyl suphate by soaking in a solution containing 1 ml DES per 1000 ml of distilled water for three hours. The M_1 plants were grown in Lafayette, Indiana, during 1972 and each head was bagged to ensure self-fertilization. M_2 plants were then grown in Puerto Rico during the winter of 1972/73 and each M_2 head was again bagged to ensure self-fertilization. Approximately 23,000 bagged M_2 heads bearing M_3 seeds were harvested in the spring of 1973 in Puerto Rico and shipped to Lafayette for evaluation.

Seed from each head was threshed and examined for opaque kernel segregates over a light box. A total of 445 putative opaque mutants were identified and seed from each segregating head was separated into vitreous and opaque classes. Both classes of seed from each putative mutant head were then analysed for protein and lysine concentration. Of the 445 mutants, only 33 were identified that had an increase in lysine concentration greater than 50%. Plants from each of these 33 opaque and normal sib seed lots were grown in paired rows to evaluate them for any morphological changes associated with the change in endosperm phenotype. Most of the opaque mutants were found to drastically affect either plant or seed development. Only one of these 33 (P-721) was found to produce normal-looking plants and seeds. The P-721 opaque mutant produced on increase of about 60% in lysine concentration. It is a single gene that is simply inherited as a partially dominant factor. The biological value of P-721 grain is significantly higher in monogastric feeding experiments the than normal sib counterpart grain (Mohan, 1975).

VanScoyoc (1979) has examined dry-matter accumulation during grain development to determine what effect the P-721 mutant has on grain yield potential. Figure 5 presents the mean seed weight per head of P-721 opaque and normal sib heads at periods ranging from 10 to 59 days after pollination in a space-planted population.

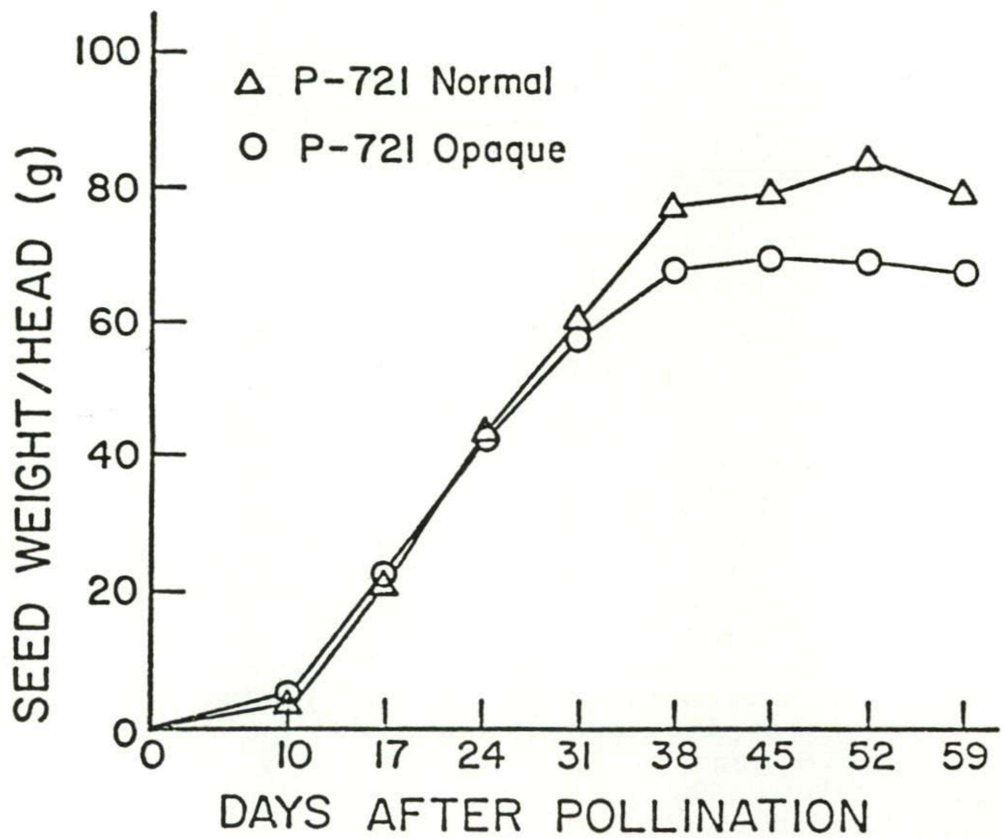

Figure 5. Mean increase in seed weight/head of P-721 opaque and P-721 normal sorghum during grain development in a space planted population.

It is evident from these data that there is no difference in dry-matter accumulation until approximately 31 days after pollination. After 31 days-dry matter accumulation in the P-721 opaque line levels off, whereas dry matter in the normal sib line continues to accumulate for an additional week, levelling off 38 days after pollination. VanScoyoc has also examined 1,000-seed weight during grain development and his data are presented in Table 3. Seed weights of the normal and opaque lines are similar up to 31 days after pollination, but diverge 38 days after pollination. At maturity, kernel weight for the opaque line is reduced 11 -14% relative to its normal counterpart. No reduction in seed number was observed, so the difference between the lines can largely be accounted for by reduced kernel density. The reduction in kernel weight is in relative agreement with preliminary data from a 1977 four-replicate yield trial at 147,664 plants/ha showing a 9.4% total yield reduction for P-721 opaque compared with its normal sib line.

Yield of P-721 derived lines

The next phase of this sorghum improvement program involved the making of hundreds of crosses of the P-721 opaque mutant with high-yielding entries from the World Sorghum Collection, with elite lines from the Purdue/AID sorghum breeding materials, and with individual plants selected from genetically heterogeneous random mating populations. Emphasis was put on incorporating the P-721 opaque gene into many and diverse genetic backgrounds to enhance the probability for identifying a genetic background which was optimal for expression of the P-721 gene. The pedigree breeding procedure was used in handling progenies from these crosses. Early generation selections were evaluated for agronomic desirability and yield potential at Lafayette, Indiana, USA, and for tropical adaptability in Puerto Rico. All segregating lines which lacked promising agronomic potential were discarded without attention to chemical evaluation because the major objective was to derive high-yielding, agronomically desirable sorghum lines in which the P-721 gene had survived. Some 197 homozygous opaque F_6 lines survived and after a final screening against lodging, stalk rot, and foliar diseases in Puerto Rico, VanScoyoc (1979) tested the best 158 lines, 11 elite normal cultivars from international trials, and RS 671 for yield (Figure 6). Several of the elite normal lines (the P-954 series) have yielded very well in Africa. Yields of the 158 P-721 lines and the 11 elite normal lines divided into three classes: 22 with low yield, 111 with intermediate yield, and 36 with high yield. All check lines were in the high-yield class. Among entries that

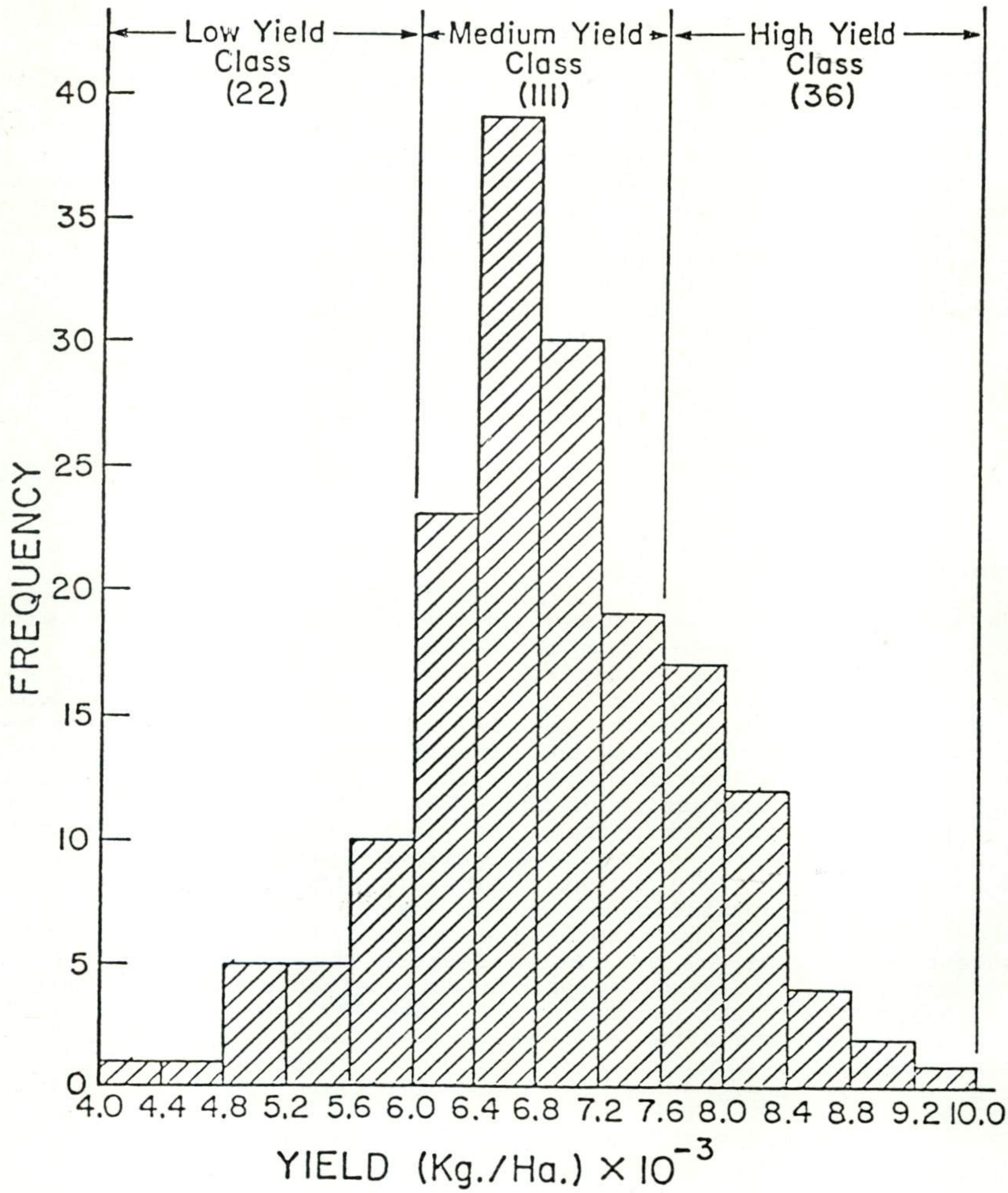

Figure 6. Frequency distribution of grain yields of F_7 P-721 opaque-derived lines and elite normal cultivars of sorghum.

yielded above 8.0 t/ha, the 12 opaque lines and the seven vitreous controls both gave mean yields of 8.5 t/ha. Among entries yielding above 7.6 t/ha, the mean for 24 opaque endosperm lines was only slightly less than that for the 12 checks (8.1 _vs_ 8.2 t/ha, respectively). These data indicate that lines with the P-721 opaque gene can yield as well as the best normal sorghum cultivars if the gene occurs in the proper genetic background. Earlier, Christensen (1978), by studying a subset of the P-721 lines in F_5 breeding lines, also showed that the P-721 opaque gene when placed in an appropriate genetic background would not reduce grain-yield potential (Table 4). Because seed weight was reduced about 15 per cent by the P-721 opaque gene, we speculate that selection for grain yield in P-721 lines must have resulted in an increase in the number of seeds per panicle and/or the number of panicles per unit area in order to have maintained a good yield level (Axtell _et al_. 1979). It is likely that variations in sorghum panicle morphology allow compensation for reduced seed weight by increasing seed number per panicle.

Table 3. Mean 1,000-seed weights of P-721 opaque and its normal sib line during grain development in a space planted population

1,000-seed dry weight* Days after pollination	P-721 normal	P-721 opaque	% P-721 opaque of normal
17	7.625	7.875	103.3
24	14.664	14.294	97.5
31	18.562	18.998	97.7
38	23.164	21.652	93.5
45	25.455	21.608	84.9
52	24.099	21.451	89.0
59	24.861	21.358	85.9

Table 4. Means of chemical and agronomic traits for opaque, heterozygous, and normal grain types in P-721 derived lines and high yielding checks of sorghum

Genotype of cultivar	No. of entries	Dye binding capacity	Protein (%)	Yield (t/ha)	Seed Weight (g/100)
Opaque	300	49.3	12.5	4.7	2.50
Heterozygous	73	42.5	13.3	4.5	2.89
Normal	5	39.8	12.9	4.2	2.87
Checks					
954063 (cultivar)	4	34.0	11.4	5.7	2.58
RS-671 (hybrid)	4	34.3	11.7	5.6	2.30
NK-300 (Hybrid)	4	33.8	10.9	6.7	2.18

Acceptance of high-lysine sorghum cultivars will be limited by problems associated with the opaque kernel phenotype. Ejeta (1979) was successful in identifying several lines with vitreous endosperm and high lysine content. Subsequently, these proved to be stable for vitreous endosperm phenotype and high lysine concentration. Also, seed treatments of P-721 opaque, high-lysine sorghum lines with DES resulted in mutants with vitreous endosperm and high lysine concentration (Porter, 1977; Ejeta, 1979). In general, the lines with modified vitreous endosperm from both sources had higher kernel weight and lower percentages of protein and lysine (Table 5). Also, the most vitreous types had the highest test weight.

A replicated yield trial of 35 opaque lines and 11 normal lines at two locations in Indiana has been completed. The results are presented in Table 6. The mean grain yield of the top three P-721 opaque lines is similar to that of the top three normal checks in the trial. The dye-binding capacity (DBC) of the high yielding P-721 derived lines is intermediate between the checks and that of the original P-721 opaque line.

Table 5. Protein and lysine content and 100-kernel weight for vitreous (modified) and opaque endosperm kernels from lines derived from P-721 high-lysine sorghum.

Endosperm type	Protein (%)	Lysine (% of protein)	100-kernel weight (g/100)
Modified	11.3	2.77	2.56
Opaque	12.6	2.83	2.27
Modified as % of opaque	90.0	97.90	112.80

Table 6. Mean grain yield of P-721 opaque derived lines in comparison with normal checks and original P-721 opaque mutant line

High lysine entry	F1 (days)	Ht. (cm)	Yield (bu/acre)	%P	DBC
851171	81	145	135	9.00	35.50
850029	82	130	131	9.07	35.00
851356	82	155	130	8.56	34.75
	82	143	132	8.88	35.08
Check entry					
954206	85	205	138	7.68	29.75
954062	81	180	132	9.32	31.50
954063	81	140	130	8.86	29.75
	82	175	133	8.62	30.33
P-721 Opaque	81	125	89	9.92	42.75

Table 7. Comparison of various results of sorghum studies with similarly obtained corresponding data from other staple foods

	Apparent N Balance		Stool Weight		Stool energy
	Absorption (%)	Retention (%)	Wet (g/d)	Dry (g/d)	(Kcal/day)
Sorghum	46	14	224	39.0	183
Wheat	81	20	95	13.3	60
Rice	66	26	67	11.6	58
Potato	66	34	165	20.3	78
Maize	73	27	133	26.8	117
Casein	81	38	95	15.5	63
Cooked (<u>Nasha</u>)	74	26	74	17	75

DIGESTIBILITY OF SORGHUM PROTEINS

Recently, nutritionists at Johns Hopkins University have conducted a series of experiements involving children in Peru using sorghum-based diets as well as diets based on wheat, rice, maize, and potatoes. Their results indicate that whole-grain sorghum is "markedly inferior" to wheat, rice, potato and maize as a source of dietary protein or energy for small children. Table 7 summarizes the results of 26 dietary sorghum periods in comparison with similarly obtained corresponding data from other staple foods. MacLean et al. (1981) concluded, "Whole grain sorghum is a bulky and poorly digestible source of dietary energy for children. The poor absorption (46 + 17%) and retention (14 + 10%) of nitrogen from sorghum in this form make it a very poor source of dietary protein in the diets of infants and children. Sorghum consumption was associated with a dramatic slowing of the rate of weight gain, which presumably resulted from excessive fecal energy losses and as a response to inadequate quantity and quality of dietary protein. The return to the control diet was associated with prompt resumption of weight gain and a rebound in apparent nitrogen retention, the latter further indicative of protein inadequacy during the sorghum period."

A search was made at Purdue for an *in vitro* system sensitive to the digestibility differences between sorghum and other cereals. Axtell et al. (1981) found that porcine pepsin *in vitro* shows these digestibility differences. The results in Table 8 show that uncooked sorghum proteins have a high pepsin digestibility (78-100%), which drops to a range of 45-55% after cooking. It is therefore essential that more research be conducted on determining the nutritional consequences of local methods of food preparation for sorghum foods in Africa, Asia and Latin America. It is assumed that the most sophisticated methods of food preparation would have evolved in areas of the world where sorghum has been used for the longest period of time, i.e. the center of origin of the crop (Ethiopia and Sudan). The results of some pepsin digestibility studies of some Sudanese sorghum breads are now complete and show clearly that local processing (fermentation) significantly improves *in vitro* protein digestibility of sorghum proteins. Two fermented sheet-baked sorghum products (*kisra* and *abrey*) from Sudan gave pepsin digestibility values of 65 - 86% (Table 9). In contrast, unfermented cooked gruels made in our laboratory from the same flours using the Johns Hopkins cooking technique gave pepsin values of only 44-56%. Therefore, fermentation improves pepsin digestibility of sorghum proteins. The digestibility values of other sorghum-based foods prepared in the semi-arid tropics need surveying. Laila Monawar from the Food Research Center in Khartoum is currently preparing a sorghum-based fermented infant food, <u>nasha</u>, for trials with children in Peru and Sudan.

Table 8. Effect of temperature on digestion of proteins by pepsin

Variety	Whole kernel*		Dehulled kernel*	
	Uncooked	Cooked	Uncooked	Cooked
IS-11758 high-lysine	88.6	45.3	78.2	41.4
954063 normal	88.9	50.6	81.7	37.1
P-721 opaque	93.0	56.7	85.7	43.0
P-721 normal	92.9	46.4	81.1	40.7

*Per cent solubilized by pepsin. Average of duplicate values.

Table 9. Effect of fermentation and temperature on digestion of sorghum proteins by pepsin

Variety	Protein %*	Uncooked**	Cooked	Laboratory Kisra**	Abrey**
Dabar	8.7	100.0	55.7	65.4	86.2
Tetran	9.0	91.4	46.7	76.0	-
Mayo	9.1	73.1	43.6	-	71.1

* Protein contents of Dabar <u>kisra</u>, Dabar <u>abrey</u>, Tetran <u>kisra</u>, and Mayo <u>abrey</u> were 11.4, 12.4, 10.4, and 8.7%, respectively.

** Per cent of protein solubilized by pepsin. Average of duplicate values.

The biochemical basis of the reduced nutritional value of some sorghum-based prepared foods remains unknown. One possibility being explored is related to the protein solubility fractionation patterns observed in sorghum as opposed to other cereals. Nwasike _et al_. (1979) showed that Landry-Moureaux fraction III in sorghum comprises a much larger proportion of the total prolamine proteins than in corn or pearl millet (Table 10). Guiragossian _et al_. (1978) first demonstrated the high proportion of crosslinked kafirins (fraction III) in sorghum endosperm from both normal and high-lysine grains (Table 11). The possibility exists that the cross-linked kafirins in sorghum are involved in the formation of complexes with starch during cooking which then reduces availability to digestive enzymes. It would be extremely useful to have a sorghum mutant with reduced fraction III kafirins to test this hypothesis, but none are available at this time.

Table 10. Nitrogen distribution in the Landry-Moureaux fractions of pearl millet, corn, and sorghum normal whole seeds

L.-M. fractions		% of total N		
		Pearl millet	Corn	Sorghum
I	Albumin-globulin	22.3	16.6	10.0
II	True prolamine	41.4	38.6	15.7
III	Prolamine-like	6.8	10.1	31.3
IV	Glutelin-like	9.3	10.0	4.5
V	True glutelin	20.9	20.2	29.3
Total N extracted		100.7	95.5	90.8
% protein in seed		14.3	10.7	13.5

Table 11. Nitrogen distribution in sorghum Endosperms[a]

Fraction	Variety P-721-N	P-721-0	IS 11167
Percentage protein (g/100 g of endosperm)	12.0	10.6	10.5
I (albumins and globulins)	9.0	28.6	23.1
II (kafirin)	25.1	9.9	10.7
III (crosslinked kafirin)	25.1	15.3	19.0
IV (glutelin-like)	6.8	4.1	4.8
V (glutelin)	34.0	42.1	42.4
Total N extracted, %	98.6	97.9	91.4

[a] Percent of soluble nitrogen.

CONCLUSIONS AND FUTURE RESEARCH

Studies of the biological value of sorghum grain for human nutrition are only beginning and the data accumulated so far are not adequate to draw any meaningful long-term conclusions. The enormous body of data from animal nutrition studies strongly suggests that, with the exception of high tannin grain, the response of livestock as well as laboratory animals fed sorghum grain is only slightly less efficient than the response from other feed grains such as maize. We also know that human populations have survived and indeed flourished on sorghum-based diets for hundreds or thousands of years. In the light of these observations, why should we be concerned about sorghum nutritional value? The answer to this question is simply that the more information we have on the nutritional value of sorghum, the more appropriately we can use this cereal grain in the future. The incentive to increase sorghum production by breeders, pathologists, entomologists, and others will depend in part on our ability to profitably utilize the increased amounts of grain produced. For example, if it becomes possible to detoxify the tannins in sorghum grain by simple inexpensive alkali treatments, the market for grain sorghum as a poultry feed in the south eastern United State will predictably expand since predatory birds are a major deterent to sorghum production in this area. Similar opportunities would exist in other parts of the world. This will only be possible through detailed biochemical and animal nutrition studies which identify the polyphenols in sorghum and define the mechanism(s) of their anti-nutritional effects.

Protein-quality research needs to be continued to determine what level of success is achievable without sacrificing grain yield or food grain quality. Here a distinction needs to be drawn between plant breeding research objectives and plant breeding objectives. Protein-quality improvement in sorghum remains a research objective at this time and is not a goal for most developing-country sorghum breeders to pursue. We remain convinced, however, that in the near future we will be able to offer methods for genetic improvement of protein quality in sorghum without sacrificing either grain yield or food-grain quality. A very substantial research effort on the molecular genetics of seed storage proteins is in progress throughout the world. Based on the knowledge and techniques gleaned from these studies we are confident that we will learn how to manipulate plant genes to design endosperm storage proteins to better meet human nutritional needs.

A great deal of research is needed to resolve the often conflicting results on the digestibility of sorghum proteins. It is imperative that the human nutritional evaluation be conducted in consort with cereal chemists and food scientists who can duplicate the local village procedures used in sorghum food preparations. It is also important to develop a center for nutritional studies in Africa so that the response of African children to their own traditional foods can be measured.

The complementarity of other foods in the diets of people using sorghum as the staple cereal must also be considered in the overall nutritional evaluation. Recently in Egypt we noted that fenugreek, a small seeded grain legume, was frequently mixed as ground flour with sorghum flour as 5% of the mixture. The fenugreek flour in the mixture added elasticity to the sorghum dough, much as gluten protein does in wheat dough. The fenugreek added significantly to the protein quality of the Egyptian sorghum bread since our analysis showed it to contain 28 % protein and 6 % lysine (expressed as per cent of protein). We do not know if the fenugreek also improves the digestibility of the sorghum proteins, but experiments are in progress to test this point. Certainly many other legumes are regularly used as complements to sorghum as well as other cereal diets, but we know relatively little about their effect on protein and carbohydrate digestibility. Much research is needed in this area.

The high *in vitro* protein digestibility of the fermented Sudanese *kisra* and *abrey* strongly suggest that local food preparation methods have evolved which improve the biological value of sorghum grain. These results need to be confirmed *in vivo*, but we suspect that this result may represent only the tip of the iceberg with regard to the interaction between village processing of sorghum and the biological value of the prepared foods. Again, a great deal of research is needed in the decade ahead.

ACKNOWLEDGEMENTS

The authors are indebted to Dr. E.T. Mertz, Karen Clymer, Mohammed Hassen, and Terry Lemming for their assistance in the collection of data and in preparation of this manuscript.

This work was supported by the U.S. Agency for International Development, INTSORMIL Project, Grant AID/DSAN/XII-G-0149. Agricultural Experiment Station, Purdue University, West Lafayette, Indiana 47907.

LITERATURE CITED

Axtell, J.D. 1981. Breeding for improved nutritional quality. In K.J. Frey (eds.), Plant Breeding II. Iowa State University Press, pp.365-432.

Axtell, J.D., Kirleis, A.W., Hassen, M.M., Mason, N.D., Mertz, E.T. and Munck, L. 1981. Digestibility of sorghum proteins. Proceedings of the National Academy of Science, USA 78:1333-1335.

Axtell, J.D., Mohan, D. Cummings, D. 1974. Genetic improvement of biological efficiency and protein quality in sorghum. Proceedings of the Twenty-Ninth Annual Corn and Sorghum Research Conference, Chicago, American Seed Trade Association, Washington, D.C. pp. 29-39.

Axtell, J.D., VanScoyoc, S.W., Christensen, P.J. and Ejeta, G. 1979. Current status of protein quality improvement in grain sorghum. Proceedings of the Symposium on Seed Protein Improvement in Cereals and Grain Legumes, 4-8 September 1978. Neuherberg, Federal Republic of Germany. pp. 357 - 363.

Butler, L.G. 1981. Polyphenols and their effect on sorghum quality. Symposium on Sorghum Grain Quality, October 28 - 31, ICRISAT, Hyderabad, India.

Christensen, P. 1978. Selection for yield and lysine concentra tion among opaque P-721 derived grain sorghum lines. Thesis, Purdue University, West Lafayette, Indiana.

Cummings, D. and Axtell, J.D. 1973. Effect of tannin content in testa (Sorghum bicolor)(L.) Moench grain on nutritional quality. Unpublished M.S. Thesis, Purdue University, West Lafayette, Indiana.

Ejeta, G. 1976. Evaluation of high lysine and normal Ethiopian sorghum varieties for protein quality, carbohydrate composition, and tannin content and an assessment of nutritional value at various stages of grain development. M.S. Thesis, Purdue University, West Lafayette, Indiana.

Ejeta, G. 1979. Selection for genetic modifiers that improve the opaque kernel phenotype of P-721 high lysine sorghum (Sorghum bicolor (L.) Monech). Ph.D. Thesis, Purdue University, West Lafayette, Indiana.

Guiragossian, V., Chibber, B., VanScoyoc, S., Jambunathan, R., Mertz, E. and Axtell, J. 1978. Characteristics of proteins from normal, high lysine, and high tannin sorghums. Journal of Agriculture and Food Chemistry 26:219.

Hulse, J.H., Laing, E.M. and Pearson, O.E. 1980. Sorghum and the millets: Their Composition and Nutritive Value. London: Academic Press.

Jambunathan, R., Mertz, E. and Axtell, J. 1975. Fractionation of soluble proteins of high lysine and normal sorghum grain. Cereal Chemistry 52: 119.

MacLean, W.C., Jr., de Romana, G.L., Placko, R.P. and Graham, G.G. 1981. Protein quality and digestibility of sorghum in preschool children: balance studies and plasma free amino acids. (In Press.).

Mohan, D. 1975. Chemically induced high lysine mutants in Sorghum bicolor (L.) Moench. Ph.D. Thesis, Purdue University, West Lafayette, Indiana.

Nwasike, C.C., Mertz, E.T., Pickett, R.C., Glover, D.V., Chibber, B.A.K. and VanScoyoc, S.W. 1979. Lysine levels in solvent fractions of pearl millet. Journal of Agriculture and Food Chemistry 27:1329-1331.

Porter, K.S. 1977. Modification of the opaque endosperm phenotype of the high lysine sorghum line P-721 (Sorghum bicolor (L.) Moench) using the chemical mutagen diethyl sulfate. Ph.D. Thesis, Purdue University, West Lafayette, Indiana.

Schaffert, R.E., Lechtenberg, V.L., Oswalt, D.L., Axtell, J.D., Pickett, R.C. and Rhykerd, C.L. 1974. Effect of tannin on in vitro dry matter and protein disappearance in sorghum grain. Crop Science 14:640-643.

Singh, R. and Axtell, J. 1973. High lysine mutant gene (hl) that improves protein quality and biological value of grain sorghum. Crop Science 13:535.

VanScoyoc, S.W. 1979. Comparison of yield and of dry matter and endosperm protein accumulation during seed development of P-721 opaque and its normal sib line, and yield evaluation of F-7 P-721 opaque high lysine derivatives with elite normal varieties of Sorghum bicolor (L.) Moench. Ph.D. Thesis, Purdue University, West Lafayette, Indiana.

SORGHUM NUTRITION AND UTILIZATION

D I S C U S S I O N

Rowland

Is the length of fermentation significant in improving digestibility?

Axtell

Our limited information suggests that this may be true up to a point.

Taye

Different lengths of fermentation periods in Ensete have indicated variation in protein quality with increase in fermentation period associated with improved protein quality.

Mann

Do the acid and alkali to^'s of West Africa have increased protein digestibility?

Axtell

No information yet but the acid in to^ may provide reducing power.

Kabiro

Regarding terminology, what would you call the product we had yesterday at the Serere Research Station? We call it beer.

Axtell

I would call it fermented porridge. I believe that in such instances the fermentation process as used traditionally has evolved not necessarily for the production of alcohol but to improve digestibility.

Oyiki

Poor sorghum drying is said to encourage aflatoxin growth. Does aflatoxin not interfere with the protein digestion and absorption?

Axtell

We have no knowledge on the role of aflatoxins on protein digestion and absorption.

Mwaule

For the benefit of those of us who are not familiar with it, could you elaborate on what is meant by diastatic power value with reference to sorghum?

Axtell

Diastatic power is the sum total of the enzymatic activity in sprouted grains which convert starch to soluble sugar and other fermentable carbohydrates. The soluble sugars are then fermented by lactobacillus and yeasts. Sorghum varieties vary considerably in diastatic power based on genotype. Some varieties are high and others low. Breeders developing sorghum varieties which will be utilized through processing by fermentation need to consider this trait if developed varieties are to be adopted.

Muhwana

You talked about ascorbic acid as one of the ways of breaking down tannins in sorghum. Can you comment further on how this is done?

Axtell

There are two concerns when we are dealing with digestibility in sorghum; the tannins are mainly protein binding and this may be remedied by soaking the grain in wood ash, and the other is the kaferin fractions of the endosperm protein and this may be overcome by adding a reducing agent such as ascorbic acid to the sorghum flour which will enhance digestibility in boiled products.

SORGHUM DISEASES: THE POTENTIAL FOR CONTROL

Richard A. Frederiksen*

Sorghum, like most agricultural commodities, is plagued by a variety of diseases. These diseases vary in importance from year to year, and among locations, due in part to the environment, plant genotypes, cultural practices, variations in pathogens, or the interaction of any of these factors.

A review of the past two decades of sorghum production in Texas, USA could be compared to that of a microbiological siege. Head smut and grain sorghum have gone hand in hand throughout this period. Initially, there were no resistant cultivars. As the first resistant varieties were developed, the head smut pathogen was able to overcome this resistance, as well as that of subsequent resistant hybrids re-introduced on a more or less intermittent basis since that time. In 1966 we experienced our first major epidemic of anthracnose. By 1968, it caused devastating losses. Although downy mildew was first observed in 1961, it was a minor problem until 1967, when the first widespread outbreak of the disease occurred, ultimately causing a shift in the hybrids grown. Since 1967, the attempts to control downy mildew have been directed primarily towards the development of disease-resistant hybrids. Shortly after the advent of downy mildew, the occurrence of a widespread, aphid-transmitted virus disease became a major concern. This disease, maize dwarf mosaic, is widely distributed and, fortunately, of less than paramount importance in Texas, but it is an annual and recurring problem.

Throughout the past two decades, leaf diseases have been, and continue to be, important menaces to crop production in South Texas. The relative importance of twelve of these is given in Table 1. While foliar diseases are generally more prevalent in wet years, major losses caused by charcoal rot and other stalk rots can be related to high temperatures and drought stress during the latter part of the growing season. Another complex disease results during extensive rainy periods during grain maturity. These conditions result in a microbial decomposition of the grain, known as grain molding or weathering. This sometimes leads to sprouting and significant losses due to test weight, quality and seed size.

---

*Professor, Department of Plant Pathology and Microbiology, Texas A&M University, College Station, TX 77843, USA

We have environment-related disease problems of sorghum, including the nutritional disorders, waterlogging, high salt concentrations in the soils resulting in poor growth and poor root development, and a host of other nutrition-related complexes with the sorghum plant. Be it hot or cold, wet or dry, good season or bad, new variety or old, it is possible that a major or damaging disease can, and in all probability will, develop in any one season.

Because of the wide variety of the types of problems encountered with grain sorghum, no one strategy by itself will necessarily be the only solution to curtailing and reducing the significant sorghum losses. Consequently, it is important that we consider all types of disease-control strategies in our quest to maximize crop production.

Table 1. The relative prevalence (a) and importance (b) of sorghum diseases.

Disease	Temperate	Sub-tropical - Tropical
1. FOLIAR DISEASES		
Leaf blight (*Exserohilum turicicum*)	++2	++1
Target leaf spot (*Bipolaris sorghicola*)	-0	+1
Anthracnose (*Colletotrichum graminicola*	+1	++3
Grey leaf spot (*Cercospora sorghi*)	+1	+++2
Zonate leaf spot (*Gloeocercospora sorghi*	+0	+++2
Sooty stripe (*Ramulispora sorghi*)	+1	++2
Rough spot (*Ascochyta sorghina*)	+1	+1
Oval leaf spot (*Ramulispora sorghicola*)	-0	++2

(Table 1. contd.)

Leaf Spot (*Phoma insidiosa*)	+1	+1
Bacterial leaf stripe (*Pseudomonas andropogoni*)	++2	+++2
Bacterial leaf streak (*Xanthomonas campestris* pv. *holcicola*)	+1	+1
Bacterial leaf spot (*Pseudomonas syringe* pv. *syringae*)	+1	+1
II. SMUTS AND RUSTS		
Head smut (*Sporisorium reilianum*)	+++3	+2
Loose smut (*S. cruenta*)	+1	+1
Covered smut (*S. sorghi*)	+1	+2
Long smut (*Tolyposporium ehrenbergii*)	-0	++2
Rust (*Puccinia purpurea*)	++1	++2
III DOWNY MILDEWS		
Sorghum (*Peronosclerospora sorghi*)	+2	+++3
Crazy top (*Sclerophthora macrospora*)	++2	+2
IV. Virus and Mycoplasm		
Maize dwarf mosaic	+++3	+++2
Sugarcane mosaic(s)	+1	++2
Yellow sorghum stunt	+1	+1
V. STALK ROTS AND ROOT ROTS		
Fusarium stalk rot (*Fusarium* sp.)	++2	++2

(Table 1. contd)

Charcoal rot (Macrophomina phaseolina)	++2	+++3
Red rot (Colletotrichum graminicola)	++2	++3
Rhizoctonia sheath blight	+1	+1
Milo disease (Periconia circinata)	+1	+1
Pokkah-boeng (Fusarium sp.)	+1	++2
Pink root (Pyrenocheata terrestis)	+1	+1
Pythium root rot (Pythium graminicola)	++3	++2
VI. HEAD AND SEED DISEASE		
Grain mold	++2	+++3
Head blight	++2	+++3
Weak neck	+1	+1
Sugary disease (Sphacelia sorghi)	-0	++2
VII. SEEDING BLIGHT (Species of Pythium, Fusarium, Rhizoctonia and Helminthosporium)	++1	++2
VIII. NEMATODES		
Pratylenchus spp	+1	++2
Meloidogyne spp.	+1	+1
IX. PARASITIC PLANTS		
Witchweed (Striga asiatica, S. hermonthica)	-0	++3

Table 1. (contd.)

X. NON-PARASITIC DISEASES		
Iron chlorosis	++2	++2
Salt damage	+1	+2
Zinc deficiency	+1	+1
Aluminium toxicity	+1	+3

(a) Prevalence:
- \- Not reported present
- \+ Occasionally present
- ++ Commonly present
- +++ Generally found on most plants in most fields to crop production

(b) Importance:
- 0 Causing no loss
- 1 Minor importance
- 2 Moderate importance
- 3 At times representing a major deterrent

METHODS OF DISEASE CONTROL

Avoidance of the pathogen

Selection of crop growing area, specific planting site, or date of planting are examples of tactics used to avoid diseases. By growing photosensitive sorghum that flowers during the dry season, one avoids grain mold. By not planting on flood plains, one can avoid crazy top downy mildew.

Exclusion of the pathogen

Pathogens can be kept from an area through regulatory means of inspection of, and certification of, seed or other plant types to ensure freedom from the pathogen or by elimination of the vector. The long smut pathogen has been excluded from the Americas by a combination of seed disinfection, inspection, quarantine, and good fortune. The same may be said for *Peronosclerospora sorghi* which has been excluded from Columbia.

Protection of the plant

Sorghum may be protected from pathogens by the use of fungicides, indirectly by control of insect vectors, or by modification of host nutrition. Currently, seed treatments are used as seed disinfectants to reduce seedling disease, control kernel smuts and downy mildews. Experimental trials in Columbia, South America, have demonstrated the economic feasibility of controlling anthracnose with fungicides.

Eradication of the pathogen

Complete eradication of an established pathogen is biologically an unlikely event. But the substantial reduction of the inoculum of the pathogen by rotation, roguing, elimination of alternate hosts or weeds, and soil treatment is possible. Destruction of johnsongrass, or other alternate hosts, or reservoirs of a number of sorghum pathogens, will be necessary to eradicate these pathogens from a specific area.

Host resistance to the disease

The most common and currently productive method of actively controlling sorghum diseases is by use of host-plant resistance. All pathogens of sorghum are affected by host reactions to some extent.

Therapy

This control method applies to the actual curing of diseased plants by chemotherapy, physical treatment or surgery. Therapy is rarely used in field crops and has very limited economic or potential significance for sorghum.

Examples of these methods of control will be applied to the major sorghum disease problems listed above.

As a guide, Table 2 lists the major sorghum disease problem areas and the most common control strategies employed for each.

Table 2. List of some common disease groups and their applicable control categories

Disease group	Applicable disease control category
Anthracnose	Host resistance, avoidance, eradication
Mosaics	Host resistance (tolerance), eradication
Grain Mold	Avoidance, host resistance
Stalk rots	Avoidance, host resistance
Downy mildew	Host resistance, eradication, exclusion, protection
Foliar diseases	Eradication, exclusion, host resistance
Smuts	
Kernel	Therapy, exclusion
Head	Host resistance, avoidance.

SORGHUM DISEASE CONTROL

Diseases of sorghum have been reviewed in detail in several publications. Consequently, disease aetiology as such will not be covered in this report. Rather, it will stress the most likely procedures for disease control.

Anthracnose

If sorghum matures during a rainy season, or a season during which it is likely to be wet, anthracnose probably will occur. Inoculum survives in debris, may be seed-borne, or commonly survives on wild species of sorghum. Partial control is possible by growing the host so that it avoids maturing during wet weather, in rotation so that inoculum from debris is decomposed, or with freedom from susceptible and infected wild hosts such as *Sorghum halepenses* or other *Sorghum* species. If the diseases cannot be avoided, resistance to anthracnose in sorghum is available in many cultivars.

In areas where conditions favourable for disease development are shortlived, and the inoculum potential is low, a high level of resistance will not be necessary, but in more humid regions, very high levels of resistance will be necessary to avoid significant losses. Many physiological races of *Colletotrichum graminicola* exist.

Mosaics

The mosaic diseases caused by various strains of sugarcane mosaic virus are typical of the types of problems encountered by virus or virus-like, insect-vectored pathogens. These deseases appear to be present wherever sorghum is grown. Damage, of course, is related in part to the time of infection, incidence of infection, reaction of the host to the virus and an environment favouring infection.

Any or all of these factors need to be considered in our control. Since the mosaic viruses are almost exclusively transmitted by aphids, absence of the vector permits the growing of a mosaic-free crop. The virus is mechanically transmitted and non persistent, therefore, a virus source or reservoir must be present for transmission. The closer the reservoir is to the field, the more favourable the opportunity for transmission to sorghum. Generally, the virus source appears to be infected johnsongrass, sugarcane, or many susceptible grasses.

Control of these mosaic diseases is dependent in part on eradication of susceptible collateral hosts, avoidance of the vector, and host resistance. Eradication of the collateral hosts, which serve as reservoirs of virus in some areas, is often difficult because of the abundance of these hosts in non-cultivated areas or, in the case of johnsongrass and sugarcane, these crops may be cultivated and tolerate strains of the virus which cause damage to sorghum. In parts of North America and in certain regions of South America, when this happens host resistance becomes a necessity to reduce losses. Vector control on the primary host may be impractical if the migratory population is high, since transmission is very rapid. Host resistance by tolerance or immunity has been identified and is available in many cultivars.

Grain Mold

Grain mold, or weathering of grain, occurs primarily on sorghum grain following maturation. However, infection of grain begins early in development, often immediately after flowering. Should there be prolonged humid weather following flowering and during grain maturation, the naturally occurring microflora, along with the natural germination processes of the seed, will begin a process of digestion of the seeds resulting in losses in weight, size, endosperm quality and seed germination. Many sorghums grown in Africa are photo-period sensitive and initiate their flowering at the onset of the dry season, thus they avoid the problem. But since the crop must proceed to develop on limited moisture, yields are low. In this example, the trade-off of higher yields for potential grain molding becomes a major issue.

Since the disease is only threatening in humid seasons, and avoidance restricts production, current work has been aimed at selecting genotypes which resist molding in the field. This is a major thrust in our research program. Fortunately, cultivars with superior levels of resistance are being developed.

Downy Mildew

Sorghum downy mildew has spread throughout the sorghum growing regions of the world. While actual losses in sorghum in most years are often not great, the potential losses in some years are alarming. Sorghum downy mildew is a soil-borne pathogen with short-lived asexual conidia which at times permit considerable secondary spread. The disease has systemic and local-lesion phases. The former almost always results in a barren plant.

Losses of both grain yield and forage are severe with systemic infection. The sorghum downy mildew pathogen can be disseminated as oospore contaminants with seed. Consequently, attempts to exclude the pathogen through quarantine have attracted much attention. All too frequently, these quarantines have been enacted after the disease appeared, and then become legal obstacles restricting the importation of resistant germplasm.

Today, host resistance is a promising method of control. Many sorghum cultivars have good levels of resistance under field conditions unless high levels of conidia are present with an ideal environment during the first few days following seedling emergence. Few sorghims are known to be absolutely free from infection every year; that is, low levels of disease will occur with high inoculum pressures in all but a few of the most resistant cultivars known.

The systematic fungicide Apron[R] (metalaxyl) developed by CIBA-GEIGY has been used successfully, because only small quantities are necessary as a seed treatment to give complete control.

Excluding the pathogen by deep tillage of the soil is partially beneficial. Currently, trapping of soil-borne spores appears promising, as does crop rotation. Prolonged cultivation of downy-mildew-resistant hybrids greatly reduces the quantity of residual inoculum. Infected maize in the USA, for example, rarely develops oospores and maize following maize tends to eliminate the disease. In sorghum-growing regions where downy mildew is important, an oospore-producing host, a Sorghum host, must be present for the disease to reach economically significant proportions. Losses can be partly avoided by overplanting since most plants systemically infected as seedlings are poor competitors.

For maize, date of planting is more critical than for sorghum. For some unknown reason, sorghum infection occurs over a fairly wide range of environmental conditions. Currently, date of planting experiments show a typical bell-shaped curve, with the highest incidence of disease occurring during the more favourable planting dates. High quality, rapidly-germinating seeds tend to escape infection more than seedlings from partially deteriorated seed. Avoidance appears probable since some sorghum-growing regions, such as the Great Plains, rarely have downy mildew.

STALK AND ROOT— ROT PROBLEMS

Root and stalk rots are very complex. The most widespread and damaging, charcoal rot, caused by Macrophomina phaseolina, only develops during periods of high temperature and when plants are undergoing a drought stress. In general, higher-yielding, weak-stalked, densely planted cultivars will develop charcoal rot more rapidly than the opposite. Control becomes a management compromise.

Under irrigation, charcoal rot is generally not a problem. Sorghum grown under rain-fed conditions rarely develops charcoal rot if plant densities are low. The severity of the disease is directly related to the rapidity of onset and severity of the temperature-mosture stress. Hence plants that are hardened off are less likely to become diseased than those receiving numerous, light rainfalls, promoting shallow rooting, followed by a prolonged dry period.

Early harvesting will avoid the losses per se, but wet grain must be dried before it can be safely stored. Work to improve the degree of resistance to charcoal rot and resulting lodging shows promise. Today, selected cultivars have moderately good levels of resistance to lodging. Many of the dwarf soghums are less likely to lodge than similar taller sorghums. Fusarium stalk rot develops under conditions similar to charcoal rot and may at times occur simultaneously. Fusarium will, in addition, develop during periods of wet weather as well (note grain mold, anthracnose and leaf blight sections). In these examples, the disease spreads from infected peduncles downward to the node, resulting in weak neck symptoms and lodging.

As for charcoal rot, several experimental lines have promising levels of resistance, but cultivars from these experimental lines have not been widely deployed.

The pathogens causing these diseases are ubiquitous and exclusion of the inoculum for either is unlikely. Cultivation of certain highly susceptible cultivars must be avoided in areas where the diseases occur.

Currently, of the root rot-diseases, only pythium root rot results in lodging. Seedling root rot, caused by various species of fungi, occasionally contributes to poor or irregular stands. Planting of poor-quality seed in soil too wet or too dry, too hot or too cold, generally predisposes sorghum to fungus seedling diseases.

SMUT

Covered kernel smut and, to a limited extent, loose kernel smut, would cause major losses if seed treatment fungicides were not used. Prior to the use of seed dressings in North America kernel smuts caused extensive yield losses. Safe, effective treatments are available and labelled for use in the USA. Head smut has not been controlled chemically. Emphasis has been placed on control through host resistance. Eradication procedures seem less likely because the inoculum is very persistent in the soil; however, in many humid sorghum-producing areas, head smut has not become a major problem. The disease appears confined to the more arid regions where soghum is grown under rainfed conditions or irrigation. For unknown reasons, in some areas heads smut rarely develops or, to date, the incidence of disease remains low. This information is useful for avoiding the disease. In sorghum-producing areas with a high probability of head smut, variation in the pathogenic population has caused concern. In Texas, USA, several new physiological races of *Sporisorium reilianum* have appeared during the past two decades. Monitoring of host resistance in conjunction with pathogen variants has, unfortunately, become a necessity. Currently, the continuous cultivation of one cultivar in areas with past histories of smut is not a safe practice. Rather, rotation of cultivars with different reactions to smut would tend to reduce the shifts in smut population brought about by monoculture. The development of alternate controls for head smut is a key objective for researchers in areas where head smut is a major problem.

FOLIAR DISEASES

Sorghum is plagued by a broad range of foliar pathogens. Some cause diseases which occur over a wide variety of environmental conditions. *Gloeocercospora sorghi* causes a seedling desease as well as severe foliar damage on mature plants. Rust occurs on foliage, peduncles and in rachis branches. It is more severe under moderately cool (16-26°C) than higher temperatures. Leaf blight also develops during cooler weather on younger plants. Fully expanded mature leaves on booting or older plants are quite unlikely to develop the disease. These leaves, however, are at a favourable stage for colonization by *Cercospora sorghi*, *Ramulispora sorghi* and *Gloeocercospora sorghi*. Bactrial stripe develops over a wide variety of environments. A few cultivars are unusually susceptible.

For most of these foliar diseases other than rust, and perhaps *Exserohilum* leaf blight, initial disease severity is often related to the previous cropping history. Consequently, disease can be avoided by practices which will reduce the over-seasoning inoculum. Rotation and destruction of debris tend to reduce initial levels of disease. Damage caused by many foliar pathogens can be avoided by the cultivation of taller genotypes of sorghum because many of these pathogens invade primarily the lower leaves. Concurrently lower plant populations, which permit better air drainage, also contributes to less foliar disease. Some air-borne foliar pathogens are much less affected by these practices, consequently, host resistance becomes a major consideration. Resistance to rust and leaf blight is known. Leaf blight inoculum spreads from infected collateral hosts such as other *Sorghum* spp. Eradication of these hosts will reduce the probability of serious losses.

Similarly, intercropping of sorghum with leaf-blight-susceptible Sudangrass or sorghum-Sudangrass hybrids should be avoided. Losses caused by disease can at times be avoided by arranging planting dates so that the crop can be grown in seasons when these diseases are less likely. Rust and leaf blight generally are much less damaging when temperatures exceed 35^0C.

Host resistance is available for moderate levels of resistance to most of the foliar pathogens. Highly susceptible varieties should not be grown; on the other hand, very high levels of resistance to any one foliar disease are not necessary. The concepts of generalized disease resistance -- those types of resistance which reduce the rate and spread of disease in a population of plants -- are preferred for sorghum.

WILT

Acremonium wilt is the only known sorghum wilt. It has been observed in many sorghum-growing regions of the world. It is of concern because some sorghums developed from a conversion program, with excellent general adaptation to the tropics, are susceptible to this disease. Acremonium wilt has been observed to be quite damaging in Hondurus, Venezuela and Argentina.

NUTRITIONAL DISORDERS

Host nutrition as a means of combating disease is poorly understood. Clearly, unproductive, poorly nourished plants are less damaged by a variety of pathogens than those with succulent growth. Poor-yielding plants have less yield to lose than thriving plants. Chlorosis, caused by non-availability of iron or zinc, is a major deterrent to production in some sorghum-production areas. In some instances, these nutritional problems enhance susceptibility to some root and foliar pathogens.

Furthermore, host genotype-nutritional interaction is quite important. Recent advances have been made in the selection of sorghums with tolerance to acid soils. These sorghums develop stronger root systems in shallow tropical soils and are more likely to escape damage caused by stalk rots. Not too surprisingly, substantial damage can be avoided by the competitive behavior of healthy plants.

CONCLUSIONS

Integration of methods of disease control in sorghum is a long-term, constantly evolving system, as changing production patterns and germplasm alter the sorghum disease picture. Although, in general, diseases reduce sorghum productivity at least 15% annually, any one disease will vary in extent from year to year, so that the damage from diseases which were low one year may become serious in another. Varying environmental conditions and cultural practices -- minimum tillage, concepts of narrow rows and high plant populations in planting, ratooning and changing plant heights -- also alter disease patterns.

Absolute or accurate values for sorghum-disease constraints on a region-wide basis are non-existent, so that in some years losses are widespread and most farmers suffer, but even in low-disease years, losses for an individual farmer may be prohibitive. Yet, concepts regarding integrated crop protection (diseases, insects, weeds) can provide a changing pattern of disease and research approaches, as well as types of information required, to meet the changing need.

REFERENCES

Fry, W.E. 1982. New York: Principles of Plant Disease Management. Academic Press.

Mughogho, L.K. 1984. Sorghum root and stalk rots: a critical review. ICRISAT, Patancheru, A.P., India.

Tarr, S.A.J. 1962. Diseases of sorghum, Sudangrass and broom corn. Commonwealth Mycology Institute, Kew, Surrey, England.

Williams, R.J., Frederiksen, R.A. and Girrad, J.C. 1978. Sorghum and pearl millet disease identification handbook. ICRISAT Information Bulletin No.2. ICRISAT, Patancheru, A.P., India.

Williams, R.J., Frederiksen, R.A. and Mughogho, L.K. 1978. Sorghum diseases, a world review. ICRISAT, Patancheru, A.P., India.

SORGHUM DISEASES

D I S C U S S I O N

Kanyenji

My observation is that there is more long smut attack on the late varieties than on the early ones. Could there be any relation between smut attack and earliness?

Frederiksen

Only as it relates to disease escape.

Rai

I would like to add another example on escape mechanisms in relation to plant height. In pearl millet, our experience is that dwarfs set more smut than tall ones. However, these observations on smut in talls and dwarfs are based on genotypes which are different not only for height gene but also for a whole lot of characters. We have now available with us 13 parts of isogenic lines at the A2 gene locus. These lines can be used to study the smut escape mechanism in relation to height. We shall be glad to supply the seeds to any one interested.

Kanyenji

Is long smut seed or soil- borne?

Frederiksen

It is not seed-borne - rather soil borne spores infest leaf ligules and infest emerging florets in the panicle.

Odongo

How much success has there been in reducing the severity of diseases by controlling insect vectors?

Frederiksen

Most of the success in controlling virus or virus-like diseases has been with the selection of host-plant resistant cultivars.

Adipala

Plant mixtures generally record less disease incidence. Unfortunately, agricultural development appears to favour monocultures. Would mixtures still be good indexes for screening trials?

Frederiksen

It is important to know that the plant phenotypes can be similar but with different genetic traits for resistance. These "mixtures" are even more modern than the idea of line varieties.

Kirkby

Your advocacy of genotype mixtures as a breeder's strategy is welcome. For information, Serere's SATU cotton varieties have been based on mixtures for about 30 years.

Sehene

I think we have a nematode problem in Rwanda. Would you please elaborate regarding their control?

Frederiksen

Little or no information has been documented on nematodes in sorghum.

Iputo

According to certain reports, certain pathogens, especially viruses, have a high degree of virulence such that as a new resistant variety is developed, new races of pathogens are available to overcome its resistance. Isn't breeding for resistance a self-defeating exercise in this regard?

Frederiksen

Occasionally, resistant cultivars succumb to new races of old pathogens. It is best to offer host resistance by various breeding tactics such as deploying resistance in mixtures, stacking resistance genes or by augmenting host resistance through cultivars, and biological and chemical methods.

Iputo

What do you mean by "good fortune" as a means of excluding a pathogen in your methods of disease control?

Frederiksen

Sometimes, pathogens do not develop in a region because of unfavourable environments, but exclusion receives the credit. Pathogens which have the ability to thrive in a particular geographic region probably will occur sooner or later.

Abebe

In our high-rainfall and intermediate-elevation areas, we sometimes come across lines which are plastered with leaf diseases but have excellent yield. What is your opinion towards advancing such lines?

Frederiksen

Some leaf diseases may develop too late to have any effect on final yield, unless one is interested in the forage quality.

AN OVERVIEW OF QUELEA CONTROL STRATEGIES

C.C.H. Elliot*

The red-billed quelea, Quelea quelea, is a small sparrow-like bird weighing about 20g. It lives only in Africa south of the Sahara and feeds on a natural diet of wild grass seeds. One of its favourite wild foods is the seed of the wild sorghums, including S. purpureosericeum. It is, therefore, not surprising that the species attacks the cultivated sorghum, Sorghum bicolor.

The problem that the quelea poses to agriculture comes from the bird's enormous numbers. The population in Africa has been estimated at 1,500 million, and it is found in the vast semi-arid regions of savannah bush country, away from mountain tops and forests. Most quelea never eat sorghum or any other cultivated grain, preferring to stick to their wild food. But, for ecological reasons which are not yet fully understood, sometimes a local part of the population descends on sorghum and causes devastating damage in a confined agricultural area.

One of the highest levels of sorghum damage ever reported was 51% in 35,000 ha on the Jijiga plain of Ethiopia (Jaeger and Erickson, 1980). This amounted to 18,000 tonnes having been destroyed by the birds. A similar but less well-documented loss of 50% occurred in 1981 over several thousand hectares near Hargeisa in NW Somalia, geographically not far from Jijiga (Ash, 1981). In Sudan, damage levels in sorghum of 25% (caused by quelea and doves) were reported over 5,200 ha at Rahad River, Kassala, Province and actual measurements on 15 ha at Basunda estimated the loss there at 35-40% (DWRC/USAID, 1979).

The essence of sorghum damage, as indeed of any damage caused by birds, is that it is localized in nature. It can therefore be catastrophic even involving a total loss, in small fields or farms of only a few hectares. It is very difficult to estimate losses over larger areas, and it is essential to randomize the sampling method in order to obtain accurate figures. Generally, the larger the area sampled, the lower the overall level of damage is likely to be. Thus, if the damage to a major sorghum-growing region or the percentage of a whole nation's sorghum production lost to birds is estimated, it would be most unusual to find more than about 5% lost to birds, and always the quelea would likely be the main culprit. Even in Ethiopia,

---

*Ornithologist, FAO/UNDP Quelea Control Project, P.O. Box 634, Arusha, Tanzania

which must be one of the most seriously quelea-affected countries on the continent, overall losses in the Awash Valley were 12-16% in 1976, a particularly bad year, and only 3-4% in 1977 (Jaeger and Erickson, 1980).

In addition to direct damage cause by quelea, the species may cause subtle indirect constraints on sorghum production. In many parts of Africa, farmers living in semi-arid areas are being encouraged to cultivate sorghum (and millet) in preference to maize. In central Tanzania, for example, sorghum will give a reasonable yield in almost every year whereas maize will fail six out of every eight years. Part of many countries' efforts towards achieving food self-sufficiency has been to encourage sorghum growing and thereby to reduce the food imports that result when crops fail. Unfortunately farmers are very sensitive to the presence of birds. Even small flocks may cause them alarm and anxiety which they often communicate through official channels. Any serious losses may cause a whole region to rebel against government policy directed at increasing sorghum production. Sometimes farmers will refuse to adopt a new and better variety, if first trials are attacked by birds (Brhane G., pers. comm.).

It is concluded that although the total amount of sorghum eaten by quelea in Africa is relatively small, the species can cause serious local damage. It can, therefore, both directly through damage and indirectly through the anxiety it causes, be a constraint on sorghum production. A government policy to increase sorghum production usually needs to be accompanied by strengthening of bird-control services. A variety of control techniques is available. It is the purpose of this presentation to examine the ways in which quelea damage to sorghum can be prevented or reduced and to suggest the best combination of methods which can be adopted as a control strategy in the light of present-day knowledge.

QUELEA CONTROL STRATEGIES

Table 1, at the end of this paper, lists the various methods, along with the pros and cons of each. There is a broad division into those which are lethal, involving the killing of the quelea, and those which are not. With such a multiplicity of techniques, the question must be posed as to which can be recommended to the sorghum grower. The answer will be influenced by the parameters of each situation, including the number of hectares under cultivation, how serious is the threat from quelea and the resources available to combat the birds. It will also depend on whether the advice is being given to an individual smallholder, a larger farm, a commercial, co-operative or state enterprise or to government officials who may be examining the problem at village, district, regional or national level.

It was mentioned above that farmers often respond with great anxiety to the sight of flocks of quelea in their fields. This is probably partly because a farmer hates to lose even a small proportion of his crop into which he has put so many hours of labor. Partly, the quelea is an unpredictable pest and a small initial population of a few hundred may expand into one of many tens of thousands. The result is that the farmer will often exaggerate the bird problem and the crop losses he has already suffered in order to obtain help or some sort of intervention against the birds. He will seldom attempt to evaluate the value of the crop he is likely to lose before completing his harvest, nor will he balance this against the cost of control, especially if most or all of that cost is met by the government. Anyone trying to evaluate a bird problem has, therefore, sometimes to take what the farmer says with a pinch of salt.

The first strategy which can be recommended to the smallholder is that of bird-scaring by people. The technique can be highly effective in almost every situation provided that one man is not required to protect more than one hectare. He must have a vested interest in successful protection either by direct ownership of the land through himself or his family, or by receiving a percentage of the yield in payment. He must be efficient, which requires that he be present and active in the field from dawn to dusk, but particularly in the last two hours of daylight from milky stage through to harvest. Only in the unusual circumstance of his field being near a breeding colony of quelea, from which the juveniles move directly onto the crop, will this method not work because the birds will be so hungry that they are virtually unscareable. As mentioned in Table 1, this method is unsuitable for large farms.

Any agronomic technique which is not offset by reduced yields, unpalatability, extra work or impossible planting schedules can be strongly recommended, because usually no other costs would be involved, nor the use of environmentally hazardous chemicals. However, experience in Africa to date has not been encouraging. At present the most palatable and best yielding varieties are also those preferred by birds, and the ones least susceptible to bird damage are less liked by people. There is still a possibility that varieties will be developed which are less preferred by birds during the milky stage when heavy damage can occur but which lose their bitter taste when mature. Even so such varieties may still be seriously damaged by birds if they are hungry enough and if they have no choice. Béesley and Lee (1979) tested a supposedly bird-resistant variety, Savannah 5, in an area in Botswana where quelea regularly occurred and where no other sorghum was grown. Unprotected heads yielded ony 93 grains per head compared with 1,676 for protected ones, i.e. 94% damage was suffered.

As far as adjusting the planting date to avoid birds is concerned, again experience has not been encouraging. For major cereal-producing farms, many other factors, such as availability of irrigation water, maintenance schedules for machinery, availability of labor, local customs, appear to decide when planting will take place and not the avoidance of birds. For smallholders, it is accepted practice to plant over a fairly extended period so that there is some chance that part of the crop will receive the most advantageous distribution of rain. It is, therefore, not possible to expect smallholders to plant their whole crop early to avoid birds even if they have the manpower to do so.

By contrast, the agronomic technique of reducing bird damage by reducing the attractiveness of fields to birds, with good weed and insect control, clearly makes good sense. Not only is the likelihood of bird damage reduced, but yield is increased by dealing with the other problems. More work and some cost on herbicides would be involved, but this would seem to be well compensated for by the double benefit. In fact, if farmers do not attend to weeds and yet demand bird control, their seriousness must be considered doubtful. However, as pointed out in Table 1, even clean fields will sometimes be attacked by quelea if they are hungry enough.

Another agronomic technique which deserves serious consideration is harvesting the sorghum as soon as it has reached physiological maturity but before it is completely dry. This can be done at 20-25% moisture, whereas harvesting is normally delayed until 10-12% moisture content is reached (COPR, 1976). The sorghum heads can then be dried in stooks protected by thorns or in stands built on the edge of fields. According to COPR, the technique does, however, increase harvesting time by 25%. Under heavy pressure from birds, farmers should surely be prepared to make the extra effort if it decreases the time during which the crop is exposed to birds, and given that no other solution is available.

Physical barriers are only useful for high-value crops such as trial plots typical of sorghum improvement research farms. Yet it is surprising how unwilling such farms are to invest in the necessary capital to build permanent exclusion areas where interference by quelea can be completely prevented.

Other techniques mentioned in Table 1, such as protective hats for sorghum, chemical repellents, ingested poisons, fire-bombs or nest destruction, I consider to have too many serious disadvantages or to have not been sufficiently developed to be considered important. We are therefore left with lethal methods applied to colonies or roosts by ground-sprayers or aircraft.

Aerial spraying is the technique most widely used in Africa for quelea control. With a well-organized team and a skilful pilot, a success rate of about 75% for all spray sorties can be expected. The result can often be spectacular with an immediate cessation of bird problems. Villagers will be able to give up the arduous work of trying to scare the birds out of their fields and will shower gratitude on the control team. In the case of breeding colonies, the control operation is usually straight forward provided that the colony is detected at the egg or young-chick stage. In Tanzania, the control teams rely heavily on local villagers to help them find the colonies. After all, if the villagers want their fields protected, then they should have a strong interest in helping to find the colonies. Most villages have herdsmen taking out cattle to graze in the surrounding countryside and they should come across any quelea colonies within a few kilometres of the village. Reports have then to be sent to the bird control unit through the official channels. For roosts (the places where Quelea concentrate at night to sleep) local farmers, or the staff of larger farms can have an important role in detecting where any birds feeding on the crop go to sleep at night. If accurate information is provided, the speed with which an aerial spray can be organized is much improved.

Apart from finding the roost or colony, two other important problems are posed by aerial spraying. The first is to decide when the target poses a genuine threat to crops and the second is to decide when the high cost of aerial spraying is justified. It is first necessary to decide whether at least some of the birds are involved in attacking a crop or not. Normally, if some birds are not visiting the fields, then the presence of birds will not be reported, so that a bird-control team will not be called to investigate. Sometimes birds will be present in the fields but will be eating wild grass seed around the edge or weed seed in the fields and not be causing any damage at all. If some damage is occurring, it is important to assess the number of birds present in the fields and to find out how many days remain before harvest. From these figures, it is then possible to estimate how much crop would be likely to be destroyed before harvesting is complete.

In principle, if the cost of the control operation exceeded the value of the crops likely to be destroyed, then there would be no economic justification for spraying. In practice, the decision on whether to spray or not to spray is often based on a much less scientific approach. Factors taken into account would be the extent to which the government is trying to encourage sorghum growing in the area affected, the political importance of the farmers whose fields are being attacked and the availability of an aircraft which may be able to spray this week but will not be available next week. It is much easier for a bird-control officer to yield to pressure from anxious farmers and to organize a spray, than to try to explain the scientific reasons against a spray and to risk being proved wrong. The result is that once the possibility for aerial spraying exists, there is a tendency to overspray regardless of the economic costs involved.

The decision on whether to spray breeding colonies of Quelea is scientifically more difficult than for roosts. Usually colony spraying is preventive in the sense that little damage to crops occurs during a colony cycle, but the potential exists for the tens or hundreds of thousands of juveniles produced to cause serious damage to nearby crops after breeding is complete. Studies have shown that such damage does not automatically occur but our level of knowledge has not advanced sufficiently to determine when damage will or will not occur. The result is that an arbitrary decision has to be taken as to when a colony is close enough to crops to pose a potential threat or not. According to Allan and Elliott (in press), a useful arbitrary distance is when a colony is within 30 km of crops. If it is, spraying is justified, but it is clear that such an approach is essentially simplistic.

In only two countries in Africa (Zimbabwe and Niger) have ground-sprayers been used on a regular basis for bird control. Using ground-sprayers is a new development in Africa. The principles involved in deciding when to use a ground-sprayer to spray a Quelea colony or roost are the same as for aerial spraying except that not all targets are suitable and the low costs of the ground-sprayer makes it a much more economic proposition. The target must be relatively accessible by vehicle (tractor, unimog or landrover), otherwise it will be impossible to spray. The capital cost of the two ground-sprayers available is very small compared to an aircraft, with the result that the cost of each operation consists only of the chemical and the support team. There is, therefore, more justification for spraying small targets with a ground-sprayer than with an aircraft.

Given that aerial spraying and, increasingly, ground spraying are, of all the techniques available, the ones which produce the most spectacular results, agriculturally and politically if not economically, it must be pointed out that a control strategy employing them does not end with the control of the birds. The object of bird control must be to protect crops and it is therefore necessary to follow up the spraying to show that damage has been effectively prevented. Damage-assessment surveys around control operations are an essential part of a control strategy.

CONCLUSIONS

An examination of all the different techniques available for preventing Quelea damage to sorghum suggests that the best control strategy involves the combination of bird-scaring by people, the implementation of as many agronomic techniques as possible and, finally, the use of aerial or ground spraying to control colonies or roosts which threaten sorghum cultivation. The pitfalls involved in spraying have been mentioned and it is suggested that the prevention of damage to sorghum should always be considered as a joint objective of the farmer and the bird-control unit. Thus farmers should be expected to carry out bird-scaring until the control operation can be mobilized. They should be encouraged to use the available agronomic methods to reduce damage and increase yield, especially good weed and insect control and early harvesting when bird pressure is high. They should be expected to organize local surveys to locate breeding colonies and to help to find roosts. In return, a bird-control unit should be expected to carry out aerial or ground spraying as efficiently and quickly as possible once proper reports are received. Bird-control operations should be carried out as a priority in areas where farmers offer full cooperation and only as a second priority in areas where the effort to solve the problem is all one sided. Control operations should be followed by damage-assessment evaluations to show that effective crop protection has been the result.

REFERENCES

Allan, R.G. and Elliot, C.C.H. Control Strategies in Practice. In Bruggers, R.L. and Elliott, C.C.H. (eds.). The Ecology and Management of the African Red-billed Quelea, Oxford University Press, forthcoming.

Ash, J.S. (1981). Qualitative and quantitative assessment of bird pests in Eastern Africa: Somalia. Proceedings of the Third Annual Technical Meeting, FAO/UNDP Regional Quelea Project RAF/77/042.

Beesley, J.S.S. and Lee, P.G. 1979. The assessment of bird resistance in sorghum cultivars in Botswana. PANS 25(4):391-393.

Centre of Overseas Pest Research 1976. Bird pest research project, Botswana. Final Report 1972-1975. Ministry of Overseas Development/Government of Botswana, ODM Research Scheme R2664. C.O.P.R., London.

Denver Wildlife Research Center/U.S.A.I.D. 1979. Vertebrate damage control research. Denver Wildlife Research Center, Denver, Colorado, USA.

Jaeger, M.M. and W.A. Erickson. 1980. Levels of bird damage to sorghum in the Awash Basin of Ethiopia and the effects of the control of Quelea nesting colonies (1976-1979). Proceedings of the Ninth Vertebrate Pest Conference Fresno, California.

Table 1. Techniques for controlling quelea and preventing damage to cereal crops

A. Non-lethal technicques	Advantages	Disadvantages
1. Bird-Scaring (a) By people on small holdings shouting, banging tins, pulling rope rattles, throwing stones, mud, cracking whips, placing flags, scarecrow.	Means that the farmer has the responsibility of protecting his fields himself; negligible capital cost; no cost to Govt., no toxic chemicals needed.	- A farmer by himself can protect 0.5-1 ha; therefore expansion of cereal production constrained. - If the farmer uses his family or children, other work is neglected including going to school. - Bird-scaring is hard work requiring vigilance 12 hrs/day for up to 3 months. - May not reduce overall damage, but just spread it out.

On large farms	Negligible capital cost; no chemicals	- Heavy man-power requirement and cost. - Often inefficient since employed scarers usually have no vested interest in the outcome and only work when the manager is around.
(b) By noise-making machines	Reduces heavy labor costs; no chemicals.	- Ineffective because Quelea become habituated to the noise after a few days.

2. Agronomic methods			
(a) Use varieties which are less susceptible to bird attack; tight heads, hairy awns, high tannin or other bitter taste; preferably more than one anti-bird factor combined in a single variety.	No other costs involved because no lethal control or other forms of control required.	- No sorghum variety yet developed is immune from attack by hungry birds. - Varieties which incorporate anti-bird factors such as taste, may also be less palatable to humans; have a lower price; may have lower yields offsetting any gains from reduced bird attack.	
(b) Plant the sorghum to ripen when the birds are absent on migration.	No other costs; no chemicals.	- May not be possible to plant rain-fed crops except when the rains fall; normally smallholders plant over several weeks to spread the risk in semi-arid areas, so some will usually be in conflict with birds.	- For irrigated crops, other factors influencing yield such as water availability, labor needs, may be more important than birds. - Arrival/departure times of quelea migrations may differ from year to year according to rainfall patterns in different parts of the range. This may make timing the harvest to their absence difficult in most cases.

(c) Plant a sorghum variety with a fast maturation stage to reduce the time during which birds can attack.	No other cost; no chemicals.	- Such varieties often produce lower yields and anyway minimum maturation will still be many days (>25) so there is plenty of time for bird damage.
(d) Don't grow sorghum, grow maize or ground-nuts or beans which are not vulnerable to birds.	Avoids the quelea problem altogether; no cost; no chemicals.	- In semi-arid areas, maize cannot be grown with the certainty of a good annual crop. - Local people may not accept a change in their staple diet.
(e) Harvest sorghum at physiological maturity and dry in stooks protected by thorn bush.	Reduces the amount of time; low cost; no chemicals.	- Increases harvest labor time by about 50%. - Does not prevent damage during most of ripening stage.

(f) Make the field less attractive to birds:		
- carry out effective weed control so that weed seeds do not attract birds;	- Has double benefit since with good weed control yield will be improved.	- Possibility that birds will still eat the crop even if it is 'clean', if they have no wild food source.
- carry out effective insect control so that insects do not attract birds;	- Similar double benefit.	
- remove stands of bushes or tall grasses which provide attractive perch sites for birds around the fields.	- Probably also reduces reinfestation of crop by insect pests which may not be affected by insecticides placed on the crop.	- ditto

B. Lethal techniques	Advantages	Disadvantages
1. Use of Ingested Poisons: (a) Apply the poison to the crop or to the patches where most damage is occurring.	- Kills only those birds actually causing damage since they ingest the chemical only when they eat the crop.	- Applying poison to crop may be health hazard if crop is to be used for food, or by stock. - If crop is being used as seed, germination may be affected. - Survivors may merely avoid poisoned area and attack unsprayed crop. This may mean that the whole crop has to be poisoned, which increases costs.
(b) Apply the poison to drinking points around the field.	- Can kill very large numbers of quelea and other pest birds since they often drink together in large flocks.	- Will kill any non-target animals or birds, stock or humans which use the same water; so the poisoned water has to be fenced in or guarded continuously. - Can only be successfully applied if the availability of water is limited.

2. Destruction of Quelea Breeding Colonies to Prevent Damage by Breeding Flocks and by Juveniles after Breeding		
(a) By nest destruction; pulling down nests or burning them or cutting down the trees.	- Smallholder farmers can organize nest destruction themselves without having to wait for outside help.	- Kills only the juvenile generation; the adults may move only a short distance and build a new colony. - In a big colony (5ha) the task may be enormous and require 100 people working for several days. - Burning or tree cutting may cause serious deforestation in areas where erosion is a problem.

(b) By ground-sprayers using avicide chemical.	- Ground-sprayers are relatively cheap. Resultant kill will include both adult and juvenile generations; it will solve the bird problem in the area until the harvest is in, unless new incursions occur.	- The colony must be accessible to ground transport (tractor or Unimog or land-rover); if area is swampy ground-sprayers cannot be used. - Use of toxic chemicals in the environment always undesirable from pollution and non-target hazards. - Locating the colony early enough to obtain an effective kill may be difficult if the terrain is rough.

(c) By aerial spraying using an avicide applied either by fixed-wing aircraft or helicopter.	- With a skilful pilot a very high percentage mortality may result. All bird problems in the area will normally be solved for the rest of the season provided no other colonies remain undiscovered nearby and no fresh incursions of birds from elsewhere occur. - A large number of dead birds provides a useful source of protein for local people, although they must eat them at their own risk and must cook them thoroughly.	- Aircraft, especially helicopters, are very expensive so the control operation may not be cost-effective. - Pollution and non-target kills may result. - Aerial spraying is usually carried out by a Govt. crop protection service, with the result that farmers may demand the service even when the damage being caused by birds is insignificant.

3. Destruction of Quelea Roosts near Vulnerable cereal Cultivation and/ or which are Attacking Crops		
(a) By fire-bombs; dynamite plus petrol/ diesel mixture.	- Very effective for small dense roosts with a dry substratum; birds killed are not polluted with chemical, therefore can be used safely for human food.	- A dangerous technique requiring fully qualified explosives operators. - Expensive, also causing bush fires which may be destructive of vegetation. - Cannot be used in reed beds or any swampy roost site.

(b) By gound-spraying of avicides	- Ground-sprayers are not expensive compared to aircraft and can use relatively little avicide. - They are easy to use and some are portable so that they can be carried to the spray site.	- Only two ground-sprayers have been proven in the field, others still under development. The low volume one uses so little chemical that birds can die over a wide spread area causing hazards to non-targets. - Any technique using toxic chemicals is environmentally undesirable. - The noise of the sprayer can sometimes frighten away the birds.

(c) By aerial spraying of avicides by fixed-wing aircraft.	- Very effective on any size of roost and can kill hundreds of thousands of birds with one sortie. Normally this will solve the problem for the rest of the growing season, unless new incursions of birds from elsewhere occur. - Can provide a source of protein for local people (see above).	- Pollution and non-target hazards. - Aircraft are expensive so that if the number of birds is not large (250,000) and the cereal crop under threat, extensive, the spraying will not be cost-effective.
4. Eradicate the quelea from the whole of Africa by aerial spraying	- Would provide a permanent solution to the quelea problem.	- The task would be impossible because of the widespread breeding often in remote areas. - The task would be impossibly expensive. - The inevitable survivors would quickly breed up to previous population levels.

QUELEA CONTROL STRAGEGIES

D I S C U S S I O N S

Axtell

What are the natural predators of quelea and what hope is there for biological control?

Elliot

The predators include eagles, hawks, falcons, storks, snakes, jackals and baboons. The migratory nature of the quelea appears to result in it succeeding in leaving its predators behind when it moves from one area to another. The predators themselves live off other food 95% of the time, so their population levels are controlled by the availability of their permanent food; the quelea is only a bonus. The predator populations only very rarely reach a level high enough to make an impact on quelea concentrations.

Hussain

I have heard that the birds do not have taste, they swallow the seed without tasting. If that is true, what will be the mechanism involved in differentiating the sweet from the bitter?

Elliot

When a quelea pulls a grain of sorghum off the head or bites it off, the first thing it does is to mandibulate and remove the covering. During this procedure, it can taste bitter and sweet, but not more complex tastes.

Rowland

Have any less conventional control techniques been tried for quelea such as introduction of genes having detrimental effects on the bird populations, deliberate inoculation of colonies with disease, interfering with natural migration patterns by luring the birds into areas where they will starve?

Elliot

No diseases have ever been noticed in quelea colonies so there are no pathogens available. The other suggested techniques do not seem to be realistic possibilities now or even for the future.

Mann

If we increase the area of sorghum dramatically, or increase the overall palatability of sorghums grown, will it result in an increase of bird populations, or will it dilute damage?

Elliot

Birds mostly depend on wild grasses for survival for a good part of the year. Their populations would not necessarily increase, but chances of contact with the crop would be increased and thus damage would likely also increase.

M'Ragwa

We noticed in one of our trials planted to a brown local sorghum with testa and red-seeded variety without testa, that the local variety was preferred to the red by the birds. It seemed that there was color preference by the birds.

Elliot

Tests on color preference in quelea have shown that some colors are preferred to others. Maybe red is less preferred or otherwise the birds had learnt from earlier experience that red was associated with bitterness.

M'Ragwa

In areas of bimodal rainfall, we think that planting sorghum in October (Kenya season) and ratooning it in February and letting the ratoon crop mature will help sorghum escape the quelea build-up in August, as the crop is harvested in June/July. Have you tried this method as one control method?

Elliot

No, but it sounds a good idea. Only practice will show whether it will work every year. Given the tendency for the quelea's migration times to vary a little every year, I guess that it would not work every year, but maybe often eough to make it worthwhile.

Doggett

Preferential feeding is certainly important, and birds will compeletely strip the most bitter sorghum types if no alternative food is available. The real problem arises from the very palatable white corneous sorghums. These are eaten in preference to either grass seeds or other sorghum types. Thus, only brown sorghums can be grown in eastern Shinyanga district in Tanzania, adjacent to the Wembere Steppe, but white corneous types are grown in W. Shinyanga.

In many parts of Africa, brown sorghums are grown for this reason. Sweet and white sorghums are more popular, maize is more acceptable and easier to prepare than brown sorghums. There is, therefore, a swing towards maize growing in ecologically unsuitable areas, or pressure to destroy birds so that the white very palatable types can be grown. The answer probably lies in developing methodologies for food preparation for brown sorghum matching those already in use but much more convenient to use. We heard of some of the problems from Dr. Axtell's presentation this morning.

Taye

Could the locust control approach be utilized for controlling the quelea and would a continental campaign to destroy the birds be applicable?

Elliot

I think the comparison, which is often made, between quelea and locusts is inappropriate. The locust plagues develop from relatively localized erruption zones. This allows control to be effectively carried out at source and plagues are thereby prevented. For quelea, our studies have shown a very wide distribution of breeding sites and many of the colonies are located in remote areas where there are no people to help report the birds. Therefore, controlling quelea at source would involve enormous expense out of proportion to the damage being caused. A continental campaign would presumably be aimed at locating all the breeding colonies and spraying them. This would require transects about 2 km apart over the whole of semi-arid Africa. The costs would be very high and inevitably some colonies would be missed. Given the ability of two parent quelea to produce at least 6, and perhaps, 12 young per year, it would not take more than a few years before the population would grow back to its previous level. Meanwhile other species which are more difficult to control than quelea might expand and cause increasing damage to crops.

Rai

What is the longevity of the quelea?

Elliot

The quelea suffers heavy mortality in the first six months of its life, with the result that the average life span is probably less than two years. However, if they survive the first months, they can live up to six or eight years.

Kabiro

What precautions are taken to fight birds in Asian countries where rice is mostly grown so that we can perhaps use the same methods to protect our sorghums in Africa?

Elliot

The population there is very low as there are no expanses of grassland, as in Africa, that foster bird populations.

Khizzah

Introduction of sterile males has been successfully used in controlling some insect pests. Is it possible to try this method in the control of the quelea?

Elliot

The idea of using chemo-sterilants to sterilize quelea has been talked about. The problem is that one is dealing with such a large population of birds that probably a chemo-sterilant would have to be applied by air. Given that the population turn-over is so quick (every two years), it would be necessary to apply the chemo-sterilant to more than 50% of the total population. This would present logistical problems. Meanwhile, sterile adults would still be able to damage crops.

Odongo

Realizing that quelea are trapped and eaten in many parts of Uganda, notably northern Uganda, and maybe elsewhere, is it not more practical for scientists to exploit this traditional technology and develop it further, for example, designing nets to trap these protein-rich flying animals for local or export human consumption?

Elliot

I think the idea of exploiting quelea for food is a challenging one. I have personally investigated the possibility of a luxury food market in southern Europe and the demand is there, though the economics need to be worked out. In certain parts of Africa (Zimbabwe, Chad, Cameroon), quelea are also netted by traditional means for local consumption. Both aspects could do with a follow-up. But I am sure that in the case of quelea, capturing them for food would not be sufficient to make any control impact on the vast populations.

Okello

Does quelea migration coincide with crop harvests in the areas they migrate to or do they just migrate to breeding areas? What determines where they migrate to? A knowledge of this would probably help to solve the problem to a certain extent.

Elliot

The migration of quelea is related to the rainfall front movement caused by the Intertropical Convergence Zone, and has been evolved over many centuries. The contact between birds and crop harvests is therefore coincidental, except that the crops are also timed to the rainfall availability. The bird migrations take them from one area of food (wild grass seed produced by rain) to another area of good natural food. We have tried to understand the migrations in eastern Africa but it is a highly complex situation involving the mixing up and separating of sub-populations. Although more knowledge about the migration patterns would help to control the birds more effectively, it does not appear that sufficient resources are available to pay for the sort of large research team needed to sort out the matter.

STEM-BORER INCIDENCE IN SORGHUM INTERCROPPED WITH MAIZE AND COWPEA TESTED IN KENYA

E.O. Omolo*

The use of intercropping systems as a cultural method of insect-pest control is based on the principle of minimizing insect pest populations by increasing the diversity of an agro-ecosystem. Smith (1970) cautioned that the same kind of diversity can be harmful in one instance and beneficial in another. Therefore one cannot generalize unless tests have been conducted in different ecological zones for a number of seasons in different years. The intercropping studies conducted at the International Centre of Insect Physiology and Ecology (ICIPE), Mbita Point Field Station (MPFS), on the shores of Lake Victoria in western Kenya, by Amoako-Atta and Omolo (1983) indicated significant interaction between pest populations and different cropping patterns. The incidence of pests during the minor season was much higher than that of the major season and there was a definite trend in pest population fluctuations starting with early or late colonization and subsequent build-up and establishment.

The objective of this study, therefore, was to test and confirm these findings in three different ecological zones representing the major agricultural zones in east, central and southern Africa, so that the practical relevance for the benefit of resource-poor farmers is proved beyond reasonable doubt.

MATERIALS AND METHODS

Previous work by Amoako-Atta and Omolo (1983) identified sorghum and cowpea as the best combination in terms of crop-pest control, productivity and crop loss, followed by maize and cowpea, then maize, cowpea and sorghum. The worst crop combination was maize and sorghum. These crop combinations, including monocrops of each, were planted in three different ecological zones in a randomized complete block design for two seasons in two years. The varieties used were similar to those used in previous studies, namely, Serena sorghum, Katumani maize and Ex-Luanda cowpea. The three locations where experiments were conducted were Mbita Point Field Station (low and erratic rainfall with intensive pest population), Ogongo-Lambwe Valley (one reliable season and normal pest population) and Rongo on the Kisii-Isebania road (highlands with both seasons reliable and low pest populations).

---

*Senior Research Scientist/Agronomist, International Centre of Insect Physiology and Ecology (ICIPE), P.O. Box 30772, Nairobi, Kenya

Sampling methodology was according to the standardized sampling technique developed by Amoako-Atta, Omolo and Kidega (1983) at ICIPE - Mbita Point Field Station. A large plot 24 m by 21 m, was sub-divided into a number of sub-plots, four of which were destructively sampled at two-weekly intervals throughout the season. At the end of the season, sub-plots assigned were harvested for yield and yield-loss assessment. The four cells at each sampling date were used to estimate population parameters within the treatment and the individual plants became the sampled variables within the sub-plots. The method of assessing yield loss under natural conditions was based on the procedure described by Judenko (1973) but the comparative assessment of yield sets of plants was grown under identical conditions except that one set was unattacked by the crop borers whereas the other set was attacked. Land equvalent ratio (LER) was used as a yield index. LER is defined by Perrin (1977) as the total land required under monoculture to give the total production of a crop equal to one hectare of intercrop; this is calculated by determining the ratio of yield of a crop mixture to its yield in monoculture at the same management level and with optimum monoculture populations.

The target pests were the stem borers, Chilo partellus (Swinh), Busseola fusca (Fulker), Sesamia calamistis (Hmps), Eldana saccharina (Wlk), and the cowpea pod borer Maruca testulalis (Geyer).

The parameters assessed were percentage of plants attacked, yield per hectare expressed in terms of LER, and percentage of yield lost due to crop borer-infestation. The major season was March to July and the minor one was September to December.

RESULTS AND DISCUSSION

In this study, the percentage attack was taken to be the plant response to the colonization, establishment and build-up of the stem borer. Data presented on Table 1 from Mbita Point Field Station indicate that in the minor season the average percentage of sorghum plants attacked by the stem-borer complex at 14 days after germination (DAG) was 5.62%, at 56 DAG 37.5% of the plants were attacked and by 98 DAG 73.37% of the plants were showing signs of damage. In the major season, at 14 DAG only 2.8% of the plants were attacked, at 56 DAG 23% and at 98 DAG the attack was up to 68.3%, showing that the attack on sorghum during the minor season started at a higher level and the build up was much faster than in the major season. The damage was also higher in the minor season than in the major season.

Table 1. Percentage attack on sorghum by stem borer complex at MPFS

Cropping pattern	Stem borer attack % in minor season (1982/83) days after germination							
	14	28	42	56	70	84	98	Mean
Sm mono	7.50	20.50	38.5	38.50	39.50	57.00	70.50	45.07^{b}
Sm/Mz	6.00	21.50	36.0	41.50	60.00	67.00	84.00	45.21^{b}
Sm/Cp	6.00	13.00	26.5	37.00	45.50	48.00	68.00	34.86^{a}
Sm/Cp/Mz	3.00	13.50	25.0	32.00	39.00	49.00	59.00	31.50^{a}
Mean	5.62	17.12	31.5	37.5	50.37	58.62	73.37	30.10
	Stem borer attack % in major season (1983) days after germination							
	14	28	42	56	70	84	98	Mean
Sm	3.75	14.25	19.25	26.28	42.00	62.25	75.5	35.75^{a}
Sm/Mz	3.00	13.75	22.00	28.75	48.75	63.50	74.5	36.32^{a}
Sm/Cp	3.00	8.50	13.28	18.50	31.00	31.50	49.5	26.07^{b}
Sm/Cp/Mz	1.50	6.75	14.00	18.50	25.00	40.25	56.5	23.18^{b}
Mean	2.80	10.81	17.12	23.00	36.68	53.87	66.3	30.08

Means followed by the same letter are not significantly different at the P = 0.05 level.

There were no differences in colonization at 14 DAG in the minor season, except on sorghum grown with maize and cowpea where the colonization was lowest (3.0%). Between 14 and 42 DAG, the establishment was faster on sorghum grown alone (20.5% to 38.5%) and sorghum grown with maize (21.5% to 36.5%) than sorghum grown with cowpea (13.0% to 26.5%) and grown with cowpea and maize (13.5% to 25.0%). Similarly, the build up from 56 to 98 DAG was faster in sorghum monoculture (38.5%, 39.5%, 57.0% and 70.5%) and sorghum grown with maize (41.5%, 60.0%, 67.0% and 84.0%) than in sorghum grown with cowpea (37.0%, 45.5%, 48.0% and 68.0%) or sorghum grown with cowpea and maize (32.0%, 39.0%, 49.0% and 59.0%). On the mean attack over the growing season, i.e. between 14 and 98 DAG, sorghum grown with cowpea (34.9%) and sorghum grown with cowpea and maize (31.5%) were attacked significantly less than sorghum monoculture (45.07%) and sorghum grown together with maize (45.21%).

During the major season, the colonization at 14 DAG was more or less the same, except in sorghum intercropped with cowpea and maize which was the least colonized (1.5%). The establishment between 14 and 42 DAG was similarly faster in sorghum monoculture (14.25% to 19.25%) and sorghum intercropped with maize (13.75% to 22.0%) than sorghum intercropped with cowpea (8.5% to 13.28%) or sorghum intercropped with cowpea and maize (6.75% to 14.0%). The build-up was also faster from 56 to 98 DAG in sorghum monoculture (26.28%, 42.0%, 62.25% and 75.5%) and sorghum intercropped with maize (28.75%, 48.75%, 63.5% and 74.5%) than in sorghum intercropped with cowpea (18.5%, 31.0%, 31.5% and 49.5%) and sorghum grown with cowpea and maize (18.5%, 25.0%, 40.25 and 56.5%). The mean attack over the growing season in sorghum intercropped with cowpea (26.07%) and sorghum intercropped with cowpea and maize (23.18%) was significantly less than the attack in sorghum monoculture (35.75%) and sorghum intercropped with maize (36.32%), indicating that colonization, establishment and build up was much faster in sorghum monoculture and sorghum intercropped with maize than in sorghum intercropped with cowpea or sorghum interplanted with cowpea and maize.

Data from Ogongo given in Table 2 indicate that at 14 DAG there was no sign of attack on sorghum plants. However, at 28 DAG 4.5% of sorghum plants were attacked by stem-borer complex, at 56 DAG the attack was 8.5% and at 98 DAG only 59.2% of sorghum plants were damaged. During the major season, signs of attack were noticed at 28 DAG and the mean percentage attack was 1.75%. At 56 DAG only 5.5% suffered damage and at 98 DAG only 45% of sorghum was damaged. Colonization started later in the minor season at 28 DAG and the establishment was not as fast as was the case at Mbita Point Field Station. It took a long time for the attack to be established.

Table 2. Percentage attack on sorghum by stem borer complex at Ogongo, 1982/83 seasons

Cropping pattern	Days after germination (minor season)							
	14	28	42	56	70	84	98	Mean
Sm mono	0	8.0	0.0	13.0	27.00	54.00	69.00	24.43[a]
Sm/Mz	0	6.0	8.0	16.0	37.50	60.00	64.50	27.43[a]
Sm/Cp	0	4.0	0.0	0.0	16.50	51.00	49.50	17.28[b]
Sm/Cp/Mz	0	0.0	3.0	5.0	12.00	31.50	54.00	15.10[b]
Mean	0	4.5	2.75	8.5	23.25	49.12	59.25	21.05

	Days After Germination (major season)							
	14	28	43	56	70	84	94	Mean
Sm	0	4.0	4.00	8.0	21.00	36.0	57.0	18.57[e]
Sm/Mz	0	0.0	7.00	4.0	26.00	26.0	60.0	17.57[e]
Sm/Cp	0	3.0	4.00	4.0	11.00	17.0	27.0	9.71[d]
Sm/Cp/Mz	0	0.0	0.00	4.0	17.00	15.0	36.0	10.28[d]
Mean	0	1.75	3.75	5.5	18.75	23.5	45.0	14.03

Means followed by the same letters are not significantly different at the P = 0.05 level.

Once the attack was established at 70 DAG, the build-up was much faster in sorghum monoculture (27.0%, 54.0% and 69.0% and sorghum grown with maize (37.5%, 60.0% and 64.5%) than in sorghum grown with cowpea (16.5%, 51.0% and 49.5%) or sorghum grown with cowpea and maize (12.0%, 31.5% and 54.0%). The mean attack over the growing season was statistically higher in sorghum monoculture (24.43%) and sorghum grown with maize 27.43%) than in sorghum grown with cowpea (17.28%) and sorghum grown with cowpea and maize (15.1%).

In the major season, colonization started as late as in the minor season (28 DAG) but at a much lower level. However, the establishment of attack was realized at 56 DAG. Thereafter the build-up, though at a lower rate, picked up much faster in sorghum monoculture (8.0%, 21.0%, 36.0% and 57.0% and sorghum inter-planted with maize (4.0%, 26.0%, and 60.0%) than in sorghum inter-cropped with cowpea (4.0%, 11.0%, 17.0% and 27.0%) or sorghum intercropped with cowpea and maize (4.0%, 17.0%, 15.0% and 36.0%). The mean attack over the season was significantly higher in sorghum monoculture (17.5%) than in sorghum grown with cowpea (9.71%) and sorghum grown with cowpea and maize (10.28%).

The level of attack at Ogongo was lower and started later than that at Mbita Point Field Station. This is due to the fact that the crop-borer population level at Mbita is higher, because of continuous plantings which take place at the station during off seasons with the help of irrigation. At Ogongo the crop-borer population level was normal since crops are only grown during the normal seasons. It is noted that in both places the level of attack in sorghum alone and sorghum grown together with maize was higher, the attack started earlier and the build-up was much faster than when sorghum is intercropped with either cowpea or cowpea and maize. These findings were also reported by Amoako-Atta and Omolo (1983), who demonstrated that at Mbita Point Field Station infestation and build-up was much faster than in farmers' fields at Kirindo and Ruri. This was due to the intensive pest population at Mbita.

As shown in Table 3, the infestation of sorghum plants at Rongo by stem-borer complex started much later (at 42 DAG) with an average attack of 2.94% and the build-up was not fast because at 56 DAG the percentage of sorghum plants attacked was 4.75% and at 98 DAG the attack was only 4.5%, showing no build-up at all during the major season. The mean attack over the growing season on sorghum grown with cowpea (0.34%) was significantly less than the mean attack on sorghum monoculture (2.14%), sorghum grown with maize (1.66%), and sorghum interplanted with cowpea and maize.

Table 3. Percentage attack on sorghum by stem-borer complex at Rongo, 1983 Major Season

Cropping patterns	Days after germination							
	14	28	42	56	70	84	98	Mean
Sm	0	0	6.0	0	1.0	1.0	7.0	1.14[a]
Sm/Mz	0	0	1.6	0	0	0	10.0	1.66[b]
Sm/Cp	0	0	0	0	1.3	1.1	0	0.34[c]
Sm/Cp/Mz	0	0	4.15	19.0	0	0	1.0	3.44[a]
Mean	0	0	2.94	4.75	0.57	0.52	4.5	1.81

Mean values followed by the same letters are not significantly different at the 0.05 levels.

It is only in this season that the presence of cowpea did not successfully protect the sorghum from stem borers at tri-crop level (sorghum, cowpea and maize). This could have been due to the presence of maize. The level of infestation at Rongo was much lower than that of Ogongo. This may suggest that the stem-borer population level in the high-potential areas such as Rongo is lower than that in the low-potential areas such as Ogongo and farmers' fields near Mbita Point. The low level of pests at Rongo could have been due to a number of factors, among which were use of insecticides, continuous rainfall which might have washed off most of the eggs or drowned the first-instar larvae, or the apparent inactivity of Busseola fusca (which happens to be the predominant species in the zone) or a combination of these factors.

Table 4 gives the combined percentage attack on sorghum in different cropping systems over the three locations. LER is also given. The data show that sorghum monoculture and sorghum planted with maize suffered 21.35% and 21.64% damage, respectively. These figures were significantly higher than sorghum intercropped with cowpea (14.76%) or sorghum intercropped with maize and cowpea 14.94%). There were significant differences in productivity (given in terms of LER). All the intercropping patterns except sorghum and maize indicated advantages over monoculture. This means that intercropping sorghum with cowpea realized a 9% increase in productivity, while maize and cowpea improved production by 17%. The least productive combination was sorghum and maize, where the LER value was 0.91. In general, the intercropping advantage seemed lower than in previous findings. This could have been due to low yields realized as a result of heavy attack by stem borers at Mbita Point in those years and, the seasons in Ogongo were not as good as those in Rongo. It is therefore noted that sorghum in monoculture and sorghum and maize planted together suffered much more damage than sorghum intercropped with cowpea or cowpea and maize, suggesting that cowpea protects cereals from stem borers.

Yield-loss assessments given in Table 5 show that sorghum as the main plant intercropped with cowpea lost statistically less (6.92%) than sorghum monoculture (16.67%) or planted with maize (21.12%). When planted with maize and cowpea it lost significantly less (11.35%) than sorghum monoculture (16.67) and sorghum planted with maize 21.12%). Sorghum tillers showed significant differences as well. In sorghum intercropped with cowpea, the tillers lost significantly less (11.95%) than in sorghum monoculture (30.2%) or sorghum planted with maize and cowpea (24.0%).

Table 4. Mean percentage attack by crop borers

Cropping Patterns	Sorghum PMFS	Ogongo	Rongo	Combined	(LER)
Sm	40.41	21.50	2.14	21.35[b]	1.0[a]
Mz/Sm	40.76	22.5	1.66	21.64[b]	0.91[a]
Sm/Cp	30.46	13.49	0.34	14.76[a]	0.09[b]
Mz/Cp/Sm	27.34	12.69	3.44	14.49[a]	1.17[c]
Mean	34.74	17.54	1.89		

Mean values followed by the same letters are not significantly different at the P = 0.05 level.

Intercropping has been an important component of small-farm agriculture in the tropics. Sorghum and beans grown together were among the important traditional tropical agriculture eco-systems. With the introduction of maize, particularly the new high-yielding hybrids, intercropping of maize and beans or sorghum and maize is often practiced. Several advantages have been attributed to this system, one of them being lower susceptibility to pests and diseases (Trenbath, 1976; Theunissen and Den Ouden 1980). Altieri et al. (1978) reported that the intercropping of maize with beans reduced pest populations compared to monocultures of the same crops.

Table 5. Sorghum Yield loss assessment in farmers' fields

	Yield loss in sorghum due to stem borer (%)	Yield loss in sorghum tillers due to stem borer (%)
Sorghum	16.67[c]	30.20[a]
Maize/sorghum	21.12[c]	15.85[b]
Sorghum/cowpea	6.92[a]	11.95[b]
Maize/cowpea/sorghum	11.35[b]	24.00[a]

Mean values followed by same letter are not significantly different at the P = 0.05 level.

Singh and Singh (1974 and 1977) reported that the presence of green gram, black gram and pigeon pea reduced the succession and build-up of insect pests in sorghum and pearl millet. These findings are supported by results from this study where it has been shown that the presence of cowpea reduced crop borers incidence in maize and sorghum. It is also shown that crop-borer activity on sorghum monoculture and sorghum-maize combination was significantly higher throughout the period of the study than on sorghum intercropped with cowpea or sorghum intercropped with cowpea and maize.

This means, therefore, that when maize and sorghum, both with similar plant type and host range for crop borers, are intercropped, the incidence of stem borers increases. On the other hand, intercropping them with cowpea, which is a non-host to the stem borers, considerably reduces the incidence of stem borers on both maize and sorghum. The presence of two cereals also reduced pod-borer incidence on cowpea. This study has confirmed its main objective which was to show that there was a trend in insect-pest colonization, population build-up and establishment related to different cropping patterns as well as cropping seasons, as reported by Amoako-Atta, Omolo and Kidega (1983).

CONCLUSION

Certain crop combinations, e.g. sorghum and maize, appear to promote colonization and build-up of insect pest populations, whereas others, e.g. sorghum and cowpea, hamper colonization. Similarity in plant type and host range for a particular insect pest increases its incidence. Intercropping has great potential as one of the major cultural methods of insect-pest control.

ACKNOWLEDGEMENTS

The assistance and cooperation of Messrs. K.E. Kidega and P. Ollimo during this study are very much appreciated. I also wish to thank IFAD for financing this project and the national research programs in Kenya, particularly Nyanza Agricultural Research Station, Kisii, for their cooperation. Special thanks to the Director of ICIPE, Professor Thomas R. Odhiambo, for continuous support and encouragement.

REFERENCES

Altieri, M.A., Francis, C.A., Van Schoonhoven, A. and Doll, J.D. 1978. A review of insect prevalence in maize (Zea mays L.) and bean (Phaseolus vulgaris L.) polycultural systems. Field Crops Res. 1:33-49.

Amoako-Atta, B. and Omolo, E.O. 1983. Yield losses caused by the stem/pod borer complex within maize-cowpea-sorghum intercropping systems in Kenya. Ins. Sci. Appl. 4: 39-46

Amoako-Atta, B., Omolo E.O. and Kidega E.K. 1983. Influence of maize, cowpea and sorghum intercropping systems on stem/pod-borer infestation. Ins. Sci. Appl. 4: 47-57

Judenko, E. 1973. Analytical methods for assessing yield losses caused by pests on cereal crops with and without pesticides. Tropical Pest Bulletin 2. 31 pp.

Perrin, R.M. 1977. Pest management in multiple cropping systems. Agroecosystems 3. 93-118.

Singh, K.M. and Singh, R.N. 1974. The population build-up of Pyrilla perpusilla Walker on sorghum and pearl millet under dryland conditions at Delhi. Indian Journal of Ecology 1: 12-16.

----------- 1977. Succession of insect pests in green gram and black gram under dryland conditions at Delhi. Indian Journal of Entomology 39: 365-370.

Smith, R.F. 1970. Pesticides: their use and limitation in pest management. In R.L. Rabb and F.E. Guthrie (eds.), Concepts of Pest Management. North Carolina State University, Raleigh. pp. 6-29.

Theunissen, J. and Den Ouden, H. 1980. Effects of intercropping with Spergula arvensis on pests of Brussels sprouts. Ent. Exp. App. 27: 260-268.

Trenbath, B.R. 1976. Plant interactions in mixed crop communities. In R.I. Papedick., P.A. Sanchez and G.B. Triplott (eds.) Multiple Cropping. America Society of Agronomy, Special Publication No. 27, Wisconsin.

STEM BORERS AND INTERCROPPING IN KENYA

D I S C U S S I O N

Kanyenji

Results from Katumani show that there is a significant sorghum yield reduction when sorghum is intercropped with cowpea. In your paper you indicated that sorghum/cowpea intercropping has a benefit in that the stem-borer attack is reduced. Has any work been done comparing the economic returns associated with yield loss due to nutrient competition and yield gains due to reduced stem-borer damage?

Omolo

Yields of intercropped cowpea will be lower than that of cowpea in pure stand. However, in terms of LER, intercropping sorghum and cowpea paid dividends. We have also shown that intercropping reduces weeds. Currently we have no direct comparative data on economic returns.

Alahaydoian

You mentioned some chemicals that could be extracted from the sorghum plant and sprayed on the non-host intercrop to lure the Chilo to the wrong plant. Is it proven that such a chemical would play a guiding role in the path-finding of the stem-borer to the host plant?

Omolo

ICIPE has extracted oviposition attractant from the sorghum plant susceptible to sorghum shootfly and put it on maize plants and this lured the shootfly to lay 70-80% eggs on maize, which is a normally non-host species.

Koma-Alimu

The idea of identifying a chemical to mislead insects to lay eggs on pseudo-hosts sounds interesting. In this case, organic synthesis of the chemical ingredients concerned would be needed. Are you in touch with interested synthetic chemical companies? It would be uneconomical to depend entirely on extracting the target chemical from cultivated crops.

Omolo

That is quite true. Once the target compound is identified, the chemistry/bioassay section of ICIPE would take it up, go through patenting and registration before getting in touch with a company to provide the synthetic equivalent.

Taye

What are the probable causes of reduction in insect build-up in intercrop compared to monocrop?

Omolo

When plants with similar plant types (cereals) and the same host range for a particular insect are planted together, the incidence of pests increases. Mixed-crop species have different crop canopies and differences in canopies create differences in micro-climate which, in turn, affect the population of natural enemies of these insect pests. In short, one explanation is insect behavioural changes and micro-climates.

Rai

Do you find stem-borer larvae on cowpea also and to what extent?

Omolo

We have found <u>Chilo partellus</u> egg masses on cowpea plants within intercropped plots. The number has been low but with appropriate time of planting the number of egg masses could easily be increase.

Oyiki

The minor season showed a higher degree of stem-borer attack than the major season. Could that be due to an unfavourable growth period that resulted in weaker and susceptible plants or higher insect build-up during that period?

Omolo

The stem-borer population was higher in the minor season because it had the opportunity to build up in the major season, whereas in the major season there were no crops, apart from the alternative host, during the period between minor and major season.

Mitawa

After 98 days the cowpea crop would have been harvested and the sorghum, cowpea and maize crop is essentially the same as sorghum and maize. How do you explain the significant difference between the two systems at the 98-day stage?

Omolo

I quite agree with you. After 70 days when the cowpea was already harvested, there would be no effect of cowpea. So the data showing an apparent reduction could have been due to sampling error.

RECOMMENDATIONS OF THE FOURTH REGIONAL WORKSHOP ON SORGHUM AND MILLET IMPROVEMENT IN EASTERN AFRICA HELD IN SOROTI, UGANDA, 22-26 JULY, 1985

1. The workshop recognized with appreciation and thanks a) the Government of Uganda b) the Uganda Agriculture and Forestry Research Organization (U.A.F.R.O) Sorghum and Millets Unit, c) the Serere Research Station d) the East Africa Civil Flying School e) the Semi-Arid Food Grains Research and Development (SAFGRAD) JP 31 of the Organization of African Unity and f) the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) for sponsoring, organizing and hosting the workshop.

2. The workshop also recognized with appreciation the support provided by ICRISAT, SAFGRAD, INTSORMIL, IDRC, FAO/UNDP, and ICIPE in providing and financing special invited speakers and participants for the workshop.

3. Recognizing that national programs need to be strengthened in all relevant disciplines of sorghum and millet research, it was recommended that other disciplines besides breeding/ agronomy be encouraged to participate more and get involved in future regional workshops.

4. In view of the deversified traditional food and beverage uses of sorghum and millets in the region, it would be useful to assemble and document the traditional knowledge on the eastern Africa utilization of these crops so that researchers within or outside the region could benefit from or add to them.

5. The workshop recommended that special topics to be presented and discussed in the 1986 workshop include: *Striga*, sorghum entomology and drought resistance.

6. As a follow-up of the recommendations of the previous workshop, the participants recognized with satisfaction ICRISAT's contribution in making sorghum and millet publications and literature available to sorghum/millet researchers of the region.

7. In view of the desired further expansions and strengthening of the eastern Africa regional network in sorghum and millet research the support and participation of additional funding agencies is very much welcome. It is recommended that the major thrust of such expansion of the regional program focus on strengthening the national programs of the region.

8. It is recommended that SAFGRAD place a particularly high priority in strengthening and contributing to the national programs of the region.

9. The workshop was again appreciated and commended by all the participants and recommended that it should continue to be held on annual basis. Burundi was selected as the venue for the 1986 workshop and the recommended time is mid-May.

CLOSING ADDRESS

F.K. Ovon*

Distinguished representatives of the Semi-Arid Food Grains Research and Development (SAFGRAD) Project, distinguished representatives of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), distinguished representatives of the International Development Research Centre (IDRC), participants from home and abroad, ladies and gentlemen: I wish first of all, on behalf of my minister, the Government of the Republic of Uganda, and on my own behalf to congratulate all of you for having successfully completed the objectives of the workshop that brought you here.

In this connection the concern across the eastern Africa region regarding the constraints the subsistence farmers face such as drought, *Striga*, diseases, and insect pests have been reflected in the presentations of various countries. Some solutions have also been presented and discussed for the benefit of our participating scientists. It is gratifying to note that scientific approaches to farmers' problems are moving in the direction of working together with the farmer. It is clear that there is a lot of potentially useful technology developed within various research stations across the region but is also clear that very little of such technology has yet reached the farmer.

The extension of technology assumes the existence of a relevant technological package along with the necessary transport and staff travel expenses. We realise that the majority of our population is practising subsistence farming, our governments lack the funds to develop infrastructures necessary to bring about changes, there is lack of entrepreneurship to invest in fertilizers, agro-industries, credit and finance. It is with this reality that research must keep the farmers' perspective if changes are going to be for the better. Scientists have to work with farmers and be sensitive to social, economical, political and agricultural realities affecting farmers. Dear scientists, our region will benefit very much if in work, thinking, and attitude you work beyond political boundaries in exchange of germplasm and technical information.

---

* Chief Research Coordinator, on behalf of Hon. Sam Tewungwa, M.P., Minister of Regional Cooperation, Republic of Uganda.

In this connection, I would like again to thank the various organizations, especially IDRC, ICRISAT, and USAID who have done much in the development of manpower and I would request for more sources of assistance for the region. As you may have seen and experienced, conferences of this nature are beneficial to our scientists but often our countries do not have the funds to cover the travel costs. Our governments face similar problems with expenses of training abroad.

I take this opportunity to thank SAFGRAD for accepting Uganda as a member of the 'CLUB' for we realize the benefits of collaboration in a regional grouping. Further, I wish to thank the officials of SAFGRAD and ICRISAT and our various ministries for organizing this workshop and bringing it to its successful conclusion. I have particular thanks to the participants from abroad who have come in response to the invitations. For the participants from home, your large turn-out is indicative of your enthusiasm for the workshop.

In conclusion, I once again thank you all for your active participation and would like to wish you a safe journey home.

I declare the Fourth Regional Workshop on Sorghum and Millets Improvement in Eastern Africa at Soroti closed.

LIST OF PARTICIPANTS

Burundi

Zénon Kabiro	Sorghum Breeder ISABU B.P. 795 BUjumbura Burundi

Ethiopia

Yilma Kebede	Team Leader Sorghum Research Institute of Agricultural Research Nazreth Research Station P.O. Box 103 Nazreth, Ethiopia
Abebe Menkir	Research Officer 1 Institute of Agricultural Research Nazreth Research Station P.O. Box 103 Nazreth, Ethiopia

Kenya

Ben M. Kanyenji	Sorghum Breeder Katumani Research Station P.O. Box 340 Machakos, Kenya
L.R. M'Ragwa	Agricultural Officer National Dryland Farming Research Station, Katumani P.O. Box 340 Machakos, Kenya
Newton Ochanda	Sorghum Breeder Alupe Agricultural Research Station P.O. Box 278 Busia, Kenya

Rwanda

Celéstin Sehene	Research Officer I.S.A.R. Rwerere B.P. 73 Ruhengeri, Rwanda

Somalia

Eugene-Kevork Alahaydoian	Advisor Somali Government Sorghum Improvement c/o Bay Region Agricultural Development Project P.O. Box 2971 Mogadishu, Somalia
Hussain Mao Haji	Plant Breeder Ministry of Agriculture Mogadishu, Somalia

Sudan

Cirino O. Oyiki	Plant Breeder Norwegian Church Aid Sudan Program-Torit P.O. Box 52802 Nairobi, Kenya

Tanzania

G.M. Mitawa	Agronomist TARO-Ilonga Private Bag Kilosa, Tanzania
Hamis M. Saadan	Scientific Officer TARO-Ilonga Private Bag Kilosa, Tanzania

Uganda

A.E. Akou	Ox-Cultivation Serere Research Station P.O. Soroti, Uganda
F.X. Koma-Alimu	Soil Chemist Serere Research Station P.O. Soroti, Uganda
E.Atadan	Millet Breeder U.A.F.R.O., Serere P.O. Soroti, Uganda
A.O. Dikan	Administrator U.A.F.R.O. Sorghum and Millet Unit Serere Research Station P.O. Soroti Uganda

<u>Uganda</u> (contd.)

Adipala Ekwamu	Pathologist Makerere University P.O. Box 7062 Kampala, Uganda
Peter Esele	Pathologist U.A.F.R.O. Sorghum and Millet Unit Serere Research Station P.O. Soroti Uganda
G.G. Iputo	Foundation Seed Production Serere Research Station P.O. Soroti Uganda
B.W. Khizzah	Millet Breeder U.A.F.R.O. Sorghum and Millet Unit Serere Research Station P.O. Soroti Uganda
G. Ochieng Mbuye	Agronomist Serere Research Station P.O. Soroti Uganda
C.D. Muhwana	Entomologist U.A.F.R.O. Sorghum and Millet Unit Serere Research Station P.O. Soroti Uganda
Y.W. Mwaule	Director of Research Serere Research Station P.O. Soroti Uganda
G.W. Otim-Nape	Plant Pathologist Serere Research Station P.O. Soroti Uganda

Uganda (contd.)

Ocitti P'Obwoya	Agronomist Serere Research Station P.O. Soroti, Uganda
S.E. Odelle	Millet Breeder U.A.F.R.O. Sorghum and Millet Unit Serere Research Station P.O. Soroti, Uganda
Wilfred R. Odogola	Agricultural Engineer Serere Research Station P.O. Soroti, Uganda
Benson Odongo	Entomologist Serere Research Station P.O. Soroti, Uganda
J.R. Okello	Crop Genetic Resources U.A.F.R.O. Sorghum and Millet Unit Serere Research Station P.O. Soroti, Uganda
R. Omolo	Entomologist Serere Research Station P.O. Soroti, Uganda
J.O.E. Oryokot	Agronomist U.A.F.R.O. Sorghum and Millet Unit Serere Research Station P.O. Soroti, Uganda
F.X. Ovon	Chief Research Coordinator National Research Council P.O. Box 6884 Kampala Uganda
Jim Rowland	Seed Production P.O. Kotido Uganda
John Trierweiler	Advisor to the Director Serere Research Station P.O. Soroti Uganda

Uganda (contd.)

Martin Wamala	Seed Production P.O. Kotido Uganda
Vincent Makumbi Zake	Principal Research Officer U.A.F.R.O. Sorghum and Millet Unit Serere Research Station P.O. Soroti Uganda

Yemen

Abdul Aziz Ahmed Bawazir	Sorghum Breeder El-Kod Agricultural Research Center c/o FAO P.O. Box 1188 Aden, Yemen PDR

Others

John Axtell	Sorghum Nutritional Quality Purdue University W. Lafayette U.S.A.
Taye Bezuneh	Director of Research OAU/STRC - SAFGRAD P.O. Box 1783 Ouagadougou, Burkina Faso
Hugh Doggett	Special Advisor I.D.R.C. 15 Bandon Road Girton Cambridge CB3 OLU U.K.
C.C.H. Elliot	Ornithologist FAO/UNDP Quelea Control Project P.O. Box 634 Arusha, Tanzania
Richard Frederiksen	Pathologist Department of Plant Sciences Texas A & M University College Station, TX 77843 U.S.A.

Others (contd.)

Brhane Gebrekidan	SAFGRAD Coordinator SAFGRAD/ICRISAT Program OAU/STRC JP 31 SAFGRAD P.O. Box 30786 Nairobi, Kenya
Roger A. Kirkby	Program Officer Crops and Cropping Systems International Development Research Center P.O. Box 62084 Nairobi, Kenya
John A. Mann	Sorghum Breeder Department of Soil and Crop Sciences Texas A & M University College Station, TX 77483 U.S.A.
E.O. Omolo	Agronomist ICIPE P.O. Box 30772 Nairobi, Kenya
K.N. Rai	Millet Breeder ICRISAT Patancheru P.O. Andhra Pradesh 502324 India

THE FOURTH REGIONAL WORKSHOP ON SORGHUM AND MILLET IMPROVEMENT IN EASTERN AFRICA, SOROTI, UGANDA

22 - 26 July 1985

PROGRAM

Monday 22 July

- Afternoon arrival of participants
- Registration of participants in Soroti Hotel

Tuesday 23 July

1. OPENING SESSION

Time	Item	Person
	- Chairman	V. Makumbi-Zake
0830	- Welcoming address	V. Makumbi-Zake
	- Opening address	Minister of Regional Cooperation of Uganda
	- Keynote address: looking back	Hugh Doggett
	- Background and purpose of the workshop	Brhane Gebrekidan

1030 - Coffee Break

2. HOST COUNTRY PAPERS SESSION

Crop Improvement

Time	Item	Person
	- Chairman	Hugh Doggett
	- Rapporteur	J.O.E. Oryokot
1100	- Overview of sorghum and millet research in Uganda	V.Makumbi-Zake
	- Sorghum and millets germplasm work in Uganda	J.R. Okello

	- Finger millet breeding in Uganda	B.W. Khizzah
	- Pearl millet improvement at Serere, 1965-73	E. Atadan
	- The present status of pearl millet breeding at Serere	S.E. Odelle
	- Sorghum breeding in Uganda	V. Makumbi-Zake
1300	- Lunch Break	

Agronomy and Seed Production

	- Chairman	Roger Kirkby
	- Rapporteur	B.W. Khizzah
1400	- The effect of continuous cultivation on the yields of finger millet, bulrush millet and rotational cropping at Serere	F.X. Koma-Alimu
	- Adoption of sorghum and finger millet technology in Uganda	J.O.E. Oryokot
	- The role and status of sorghum and finger millet in Teso farming system	J.O.E. Oryokot and B.A. Opolot
	- The role of ox-cultivation on sorghum and millet production in Uganda	A.E. Akou
	- Sorghum and millets - the Karamoja experience	J.R. Rowland
	- Achievements and problems of the Uganda seed industry with particular reference to sorghum and millets	G.G. Iputo
	- Agro-ecological zones and operation of variety trial centers in Uganda	G.O. Mbuye

Wednesday 24 July

Crop Protection

	- Chairman	Y.W. Mwaule
	- Rapporteur	F.X. Koma-Alimu
0800	- An overview of sorghum diseases in Uganda	J.P.E. Esele
	- Fungicidal control of fungal diseases of finger millet	E. Adipala and J. Mukiibi
	- Determination of the optimal dosage and intervals between successive applications spraying against fungal diseases of finger millet	E. Adipala and J. Mukiibi
	- Differences in resistance to rice weevil in sorghum	C.D. Muhwana
	- A survey of insect status on sorghum in northern and western Uganda	C.D. Muhwana
	- Sorghum shoot-fly research in Uganda	C.W. Balidawa
	- Bird-pest research and control strategies on cereals in Uganda	F.H.O. Akol and R. Molo
	- Preservation of bulk-stored sorghum through aeration using solar-cooled air: a non-chemical approach	W.R. Odogola
1000	- Coffee Break	

3. VISITING COUNTRIES PAPERS SESSION

Chairman	Taye Bezuneh
Rapporteur	J.P.E. Esele

1030	- A review of sorghum and millet research in western Kenya during 1984	N.W. Ochanda
	- Report of the sorghum and millet improvement program for eastern Kenya, 1984	L.R. M'Ragwa and B.M. Kanyenji
	- Sorghum food quality and utilization in Kenya	R.M'Ragwa F. Pinto J. Bunge N. Ochanda E. Mativo
	- Development and improvement of pearl millet composite in Katumani pearl millet	L.R. M'Ragwa
	- Sorghum improvement in Tanzania, 1984/85	H.M. Saadan
	- The potential for sorghum and millets research in southern Sudan with emphasis on Eastern Equatoria	C.O. Oyiki
1300	- Lunch Break	
1400	- Sorghum improvement in Ethiopia, 1984/85	Yilma Kebede and Abebe Menkir
	- Intercropping sorghum with maize at the high-elevation locations of Alemaya and Arsi Negelie	Abebe Menkir and Yilma Kebede
	- The sorghum improvement program in Somalia	E.K. Alahaydoian
	- Gene effects for resistance to stem borer in sorghum	H.M. Haji

	- Chairman	G.M. Mitawa
	- Rapporteur	M. Manyala
1600	- Sorghum research in Burundi	Z. Kabiro
	- Summary of 1984 sorghum work in Rwanda	C. Sehene
	- Sorghum and millets research in PDR Yemen during the 1984 season	A.A.A. Bawazir

Thursday 25 July

4. FIELD AND LABORATORY VISITS

All day visits to

- District Variety Trial Centers
- Serere Research Station

Friday 26 July

5. INVITED PAPERS SESSION

	- Chairman	Brhane Gebrekidan
	- Rapporteur	Yilma Kebede
0800	- Problems and methods in pearl millet breeding	K.N. Rai and J.R. Witcombe
	- Problems and prospects in sorghum nutrition and utilization	John Axtell and Gebisa Ejeta

	- Sorghum diseases: The potential for control	R.A. Frederiksen
	- An overview of Quelea control strategies	C.C.H. Elliot
	- Stem-borer incidence in sorghum intercropped with maize and cowpea tested in Kenya	E.O. Omolo
1300	- Lunch Break	
1400	- 6. FINAL DISCUSSIONS AND RECOMMENDATIONS SESSION	
1900	- Workshop dinner and closing address	

Saturday 27 July

Participants depart for home

1986-06

SORGHUM AND MILLET IMPROVEMENT IN EASTERN AFRICA

AU-SAFGRAD

AU-SAFGRAD